INSTRUCTION AND MAINTENANCE
MANUAL for
RETURN LOSS MEASURING SETS
Model 481A
Model 481B

Bowmar

WHEN QUALITY COUNTS

Communications Test Equipment

Bowmar/ALI Inc.
531 Main Street
Acton, Mass. 01720

INSTRUCTION AND MAINTENANCE MANUAL for RETURN LOSS MEASURING SETS

Model 481A
Model 481B

BOWMAR/ALI, INC.
531 Main Street
Acton, Massachusetts 01720 U. S. A.

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NOTE

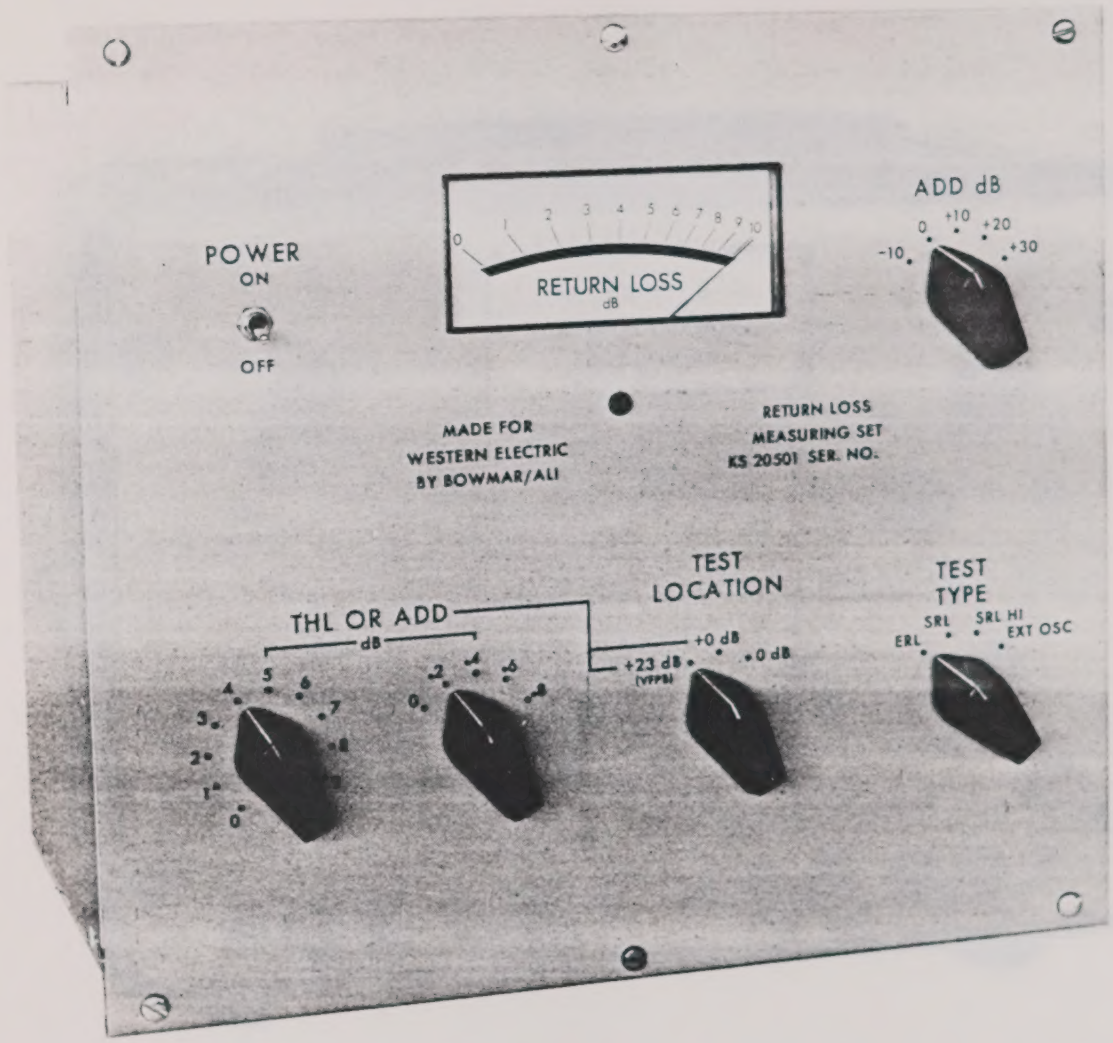
On L3 units with Serial No. s after 4600 and on L4 units with Serial No. s after 2200 the transient clippers connected across the output are communication gap surge transient voltage protectors which actuate at 145 volts. Also, the blocking capacitors C1, C2, C21, and C22 are rated at 150 volts. The units are acceptable for use on circuits such as the Metallic Facility Terminal (MFT) that operate on either 48 ± 4 VDC or 72 ± 6 VDC or circuits rated up to 105 VDC.

Prior units use neon glow lamp transient clippers which actuate at 65 volts and blocking capacitors rated at 50 volts. The units are acceptable for use on circuits that operate on 48 ± 4 VDC but should not be used on higher voltage facilities.

Note: The varistors CR18 and CR19 are deleted on L3A and L4A units manufactured after October, 1977. These varistors may be deleted from prior L3A and L4A units but should be maintained on L3 and L4 units which have neon glow lamp transient clippers.

All references to L3 apply to the L3A and all references to L4 apply to L4A throughout this manual.

RETURN LOSS MEASURING SET
Model 481A



RETURN LOSS MEASURING SET
Model 481B

TABLE OF CONTENTS

Section		Page
1	INTRODUCTION	1-1
	1.1 Description	1-1
	1.2 Scope of Manual	1-1
	1.3 Designation of Instruments	1-1
	1.4 Specification Summary	1-1
	1.5 General Background Information	1-3
	1.6 Standard Filter Curves	1-5
2	OPERATING INSTRUCTIONS	
	2.1 Controls, Jacks, and Meter	2-1
	2.2 Procedures	2-3
	2.3 Signal and Power Connections	2-5
3	CIRCUIT DESCRIPTION	
	3.1 General	3-1
	3.2 Transmitter	3-1
	3.3 Receiver	3-4
	3.4 Power Supplies	3-5
	3.5 Circuit Differences, L3 and L4 Sets	3-6
4	MAINTENANCE	
	4.1 Introduction	4-1
	4.2 Test Equipment Required	4-1
	4.3 Cabinet Removal	4-1
	4.4 Performance Checks	4-1
	4.5 Calibration and Adjustment Procedures	4-10
5	TROUBLESHOOTING TECHNIQUES	
	5.1 General	5-1
	5.2 Troubleshooting from Front Panel Symptoms	5-2
	5.3 Isolating Malfunctions	5-3
6	DRAWINGS	
	6.1 General	6-1
	6.2 List of Drawings	6-1
7	PARTS LIST	
	7.1 General	7-1

1.0 INTRODUCTION

1.1 Description

The KS-20501 Return Loss Measuring Set (Bowmar Model 481) is an instrument designed to make those measurements, for through and terminal balance in central offices, which are required to control speech echoes and prevent singing or oscillating conditions.

1.2 Scope of Manual

This manual describes the various modes of return loss measurement. It contains detailed instructions for operation, routine maintenance, and calibration, as well as trouble shooting and minor repair procedures. Schematic diagrams with typical voltages and waveforms are included, supplemented by component and path locating diagrams. A parts list, with the names and addresses of manufacturers is also included.

1.3 Designation of Instruments

The KS-20501 L3 model of the Return Loss Measuring Set (Model 481A) is a portable unit operated from a 115 V 60 Hz line. It is designed to make 2-wire and 4-wire return loss measurements.

The KS-20501 L4 model of the Return Loss Measuring Set (Model 481B) is a rack-mounted unit powered from a remote -48 V dc source and is designed to make 4-wire return loss measurements only.

1.4 Specification Summary

Test Type:	Echo Return Loss (ERL) Singing Return Loss (SRL) Singing Return Loss High Frequency (SRL HI) Single Frequency Return Loss (External Oscillator)
Modes:	2-wire, 600 and 900 ohms, L3 only 4-XB Test Hybrid VFPB
Filter Characteristics (-3 dB points):	ERL: 560 to 1965 Hz SRL: 260 to 500 Hz SRL-HI: 2200 to 3400 Hz

External Oscillator Range: 200 Hz to 15 kHz

Impedances:
2-wire: 600 and 900 ohms, L3 only
4-wire: 600 ohms
EXT OSC Input: 600 ohms

Return Loss Range: -10 dB to +40 dB

Accuracy: ±0.4 dB, all test types

Internal Hybrid Balance Network:
2.16 μF in series with 600 or 900 ohms, L3 only

4-Wire Circuit Loss Compensation:
+23 dB (VFPB): 23 dB of fixed gain inserted plus 10 dB adjustable in 0.2 dB steps
+0 dB: 10.8 dB adjustable in 0.2 dB steps
0 dB: 0 dB internal gain

Output Signal: Type: weighted white noise, with provisions for external oscillator

Output Level:
2-wire: -8 dBm for 600 ohms
-9.8 dBm for 900 ohms
4-wire: -2 dBm for 600 ohms

Longitudinal Balance: 70 dB at 100 Hz and 55 dB at 3 kHz

Fault Voltages:
(a) Any line input will withstand 600 Vdc to ground.
(b) All specifications are met when input line carries up to 105 VDC. Unit will not be damaged by 105 Vrms 20 Hz ringing signal for 10 seconds with an external loop resistance of 1500 ohms.

Primary Power:
L3: 117 Vac ± 10%, 60 Hz
L4: -48 Vdc ± 4 V

Size and Weight:
L3: 8-3/4" H x 12" W x 7-5/8" D
Approximately 15 lb. with cover
L4: 10" H x 11" W x 6-1/4" D
Approximately 12 lb.

Operating Temperature and Humidity: 0 to 50° C, 95% relative humidity

1.5 General Background Information

The general principle used in making return loss measurements is diagrammed in the hybrid 4-port network, as shown in FIG. 1-A.

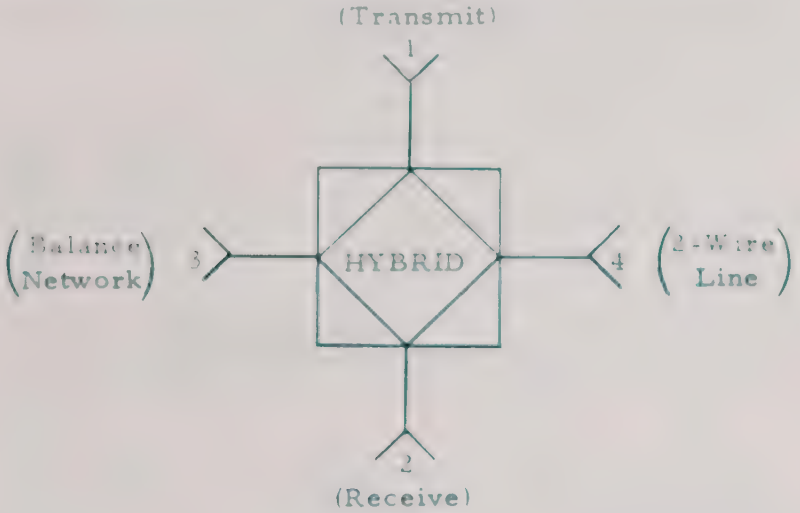


FIG. 1-A

The impedance of port 1 must equal that of port 2, and the impedance of port 3 must equal that of port 4, for the hybrid to be perfectly balanced. The attenuation from ports 1 to 4 and ports 4 to 2 is 3 dB for a transformer type hybrid and 6 dB for a resistive type hybrid.

Where α_{1-4} is the attenuation from port 1 to port 4, α_4 is the return loss of port 4, and α_{4-2} is the attenuation from port 4 to port 2, the total attenuation from port 1 to port 2 is described as in the following equation:

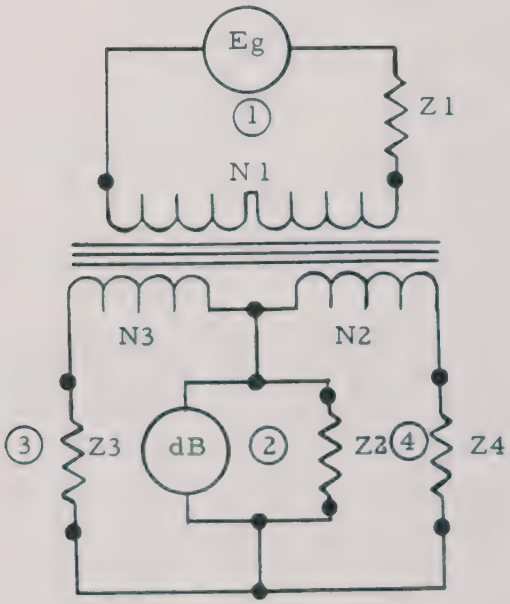
$$\alpha_{1-2}=\alpha_{1-4}+\alpha_4+\alpha_{4-2}$$

When the impedance of port 4 (2-Wire Line) does not match the impedance of port 3 (Balance Network) the attenuation from port 1 to port 2 is the return loss of port 4 plus the total attenuation from ports 1 to 4 and 4 to 2.

A return loss measurement of the impedance at port 4 can be made with a signal generator of proper impedance connected to port 1 and a dB meter of equal impedance connected to port 2. In the case of the transformer hybrid, with a known balancing network at port 3, the return loss of the unknown at port 4 is determined by measuring the signal attenuation from port 1 to port 2 and subtracting 6 dB. For example, the return loss of the network at port 4, with respect to the balancing network at

port 3, is 36 dB if the loss from port 1 to port 2 is 42 dB. It should be noted that all four port impedances must be equal in the balanced condition when using a resistive hybrid for return loss measurement. A transformer hybrid must be used when the impedances of ports 1 and 2 are not equal to ports 3 and 4. Examples of resistive and transformer hybrids are shown in FIG. 1-B and FIG. 1-C.

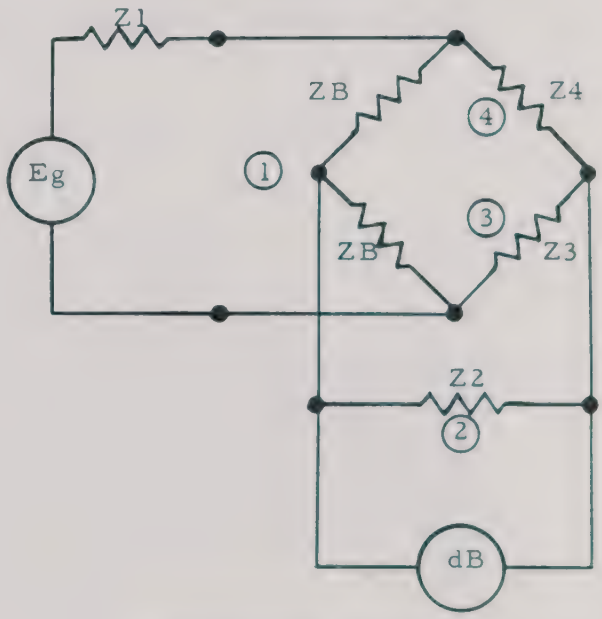
$Z2 = Z3 \quad N2 = N3$



TRANSFORMER HYBRID

FIG. 1-B

$Z1 = Z2 = ZB = Z4$



RESISTIVE HYBRID

FIG. 1-C

The return loss measurement can initially be calibrated to 0 dB return loss by open- or short-circuiting the terminals at port 4; then, when the unknown load is connected to port 4, absolute value of the new dB meter reading will be the return loss. This method of calibration is valid only if the generator and dB meter impedances are matched to the hybrid.

A method of performing ERL, SRL, AND SRL HI functions for 2-wire measurements in one unit is shown in the block diagram in FIG. 1-D.

A diode noise source provides a flat spectrum between 200 Hz and 4 kHz. Three band pass filters shape the noise spectrum to be used in the measurement. ERL (560 to 1965 Hz), SRL (260 to 500 Hz), and SRL HI (2200 to 3400 Hz) are used for measurement. The use of an external oscillator for determining exact frequency of minimum return loss is also shown.

The band limited noise signal is passed through a resistive hybrid network which uses the 2-wire line and compromise network. The null signal of the hybrid bridge, which is a measure of the return loss of 2-wire line, is passed through a meter attenuator and amplifier to the return loss meter. The meter is calibrated in dB and the total return loss is read by adding the meter indication to the attenuator switch indication.

The noise generator enables a measurement of return loss of a complete frequency spectrum at one time while the external oscillator capability provides for measuring return loss at specific frequencies.

The same basic circuitry that is shown in FIG. 1-D can be used to make balance measurements on external 4-wire terminating sets. Balance measurements are made using the 4-wire mode. The configuration for these 4-wire measurements is shown in FIG. 1-E, where the hybrid is omitted and the test set is used as both a noise generator and a level measuring set. The band limited noise signal is passed through the transmitting 4-wire line to the 4-wire terminating set. The amount of signal returned on the receiving 4-wire line is in measure of the balance of the 4-wire terminating sets. Corrections for normal attenuation in the 4-wire line can be made by a Trans Hybrid Loss (THL) amplifier which is adjustable in 0.2 dB steps from 0 to 10.8 dB. When the test is being made through a Voice Frequency Patch Bay (VFPB), an additional fixed 23 dB of gain can be inserted to compensate for the added loss.

1.6 Standard Filter Curves

Three line-graphs that represent standard filter curve characteristics are shown on pages 1-8, 1-9, and 1-10. These curves show relative attenuation in dB versus frequency in Hz for the ERL (Echo Return Loss), SRL (Singing Return Loss), and SRL HI (Singing Return Loss High Frequency) filters.

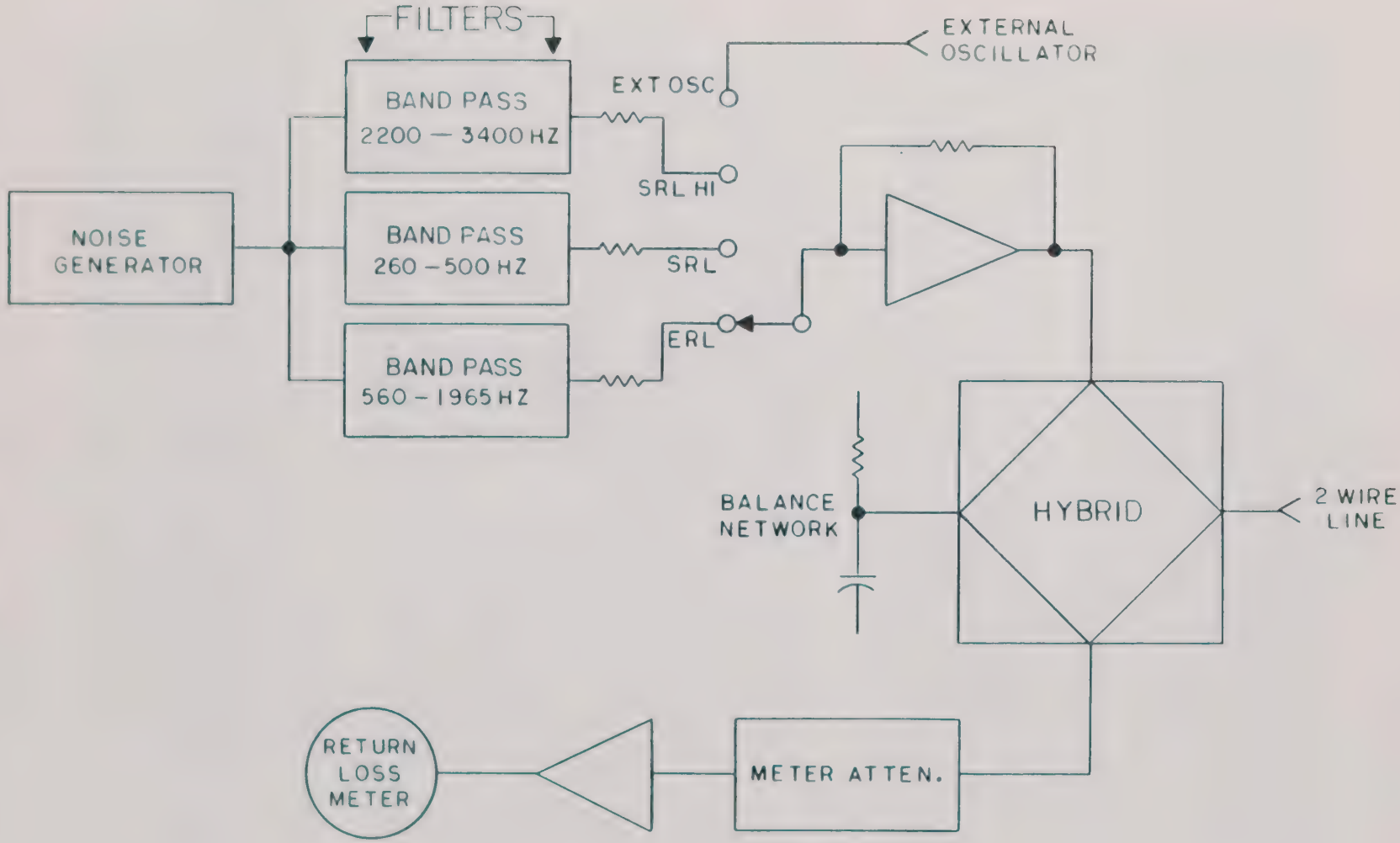


FIG. 1-D

2-WIRE LINE MEASUREMENTS

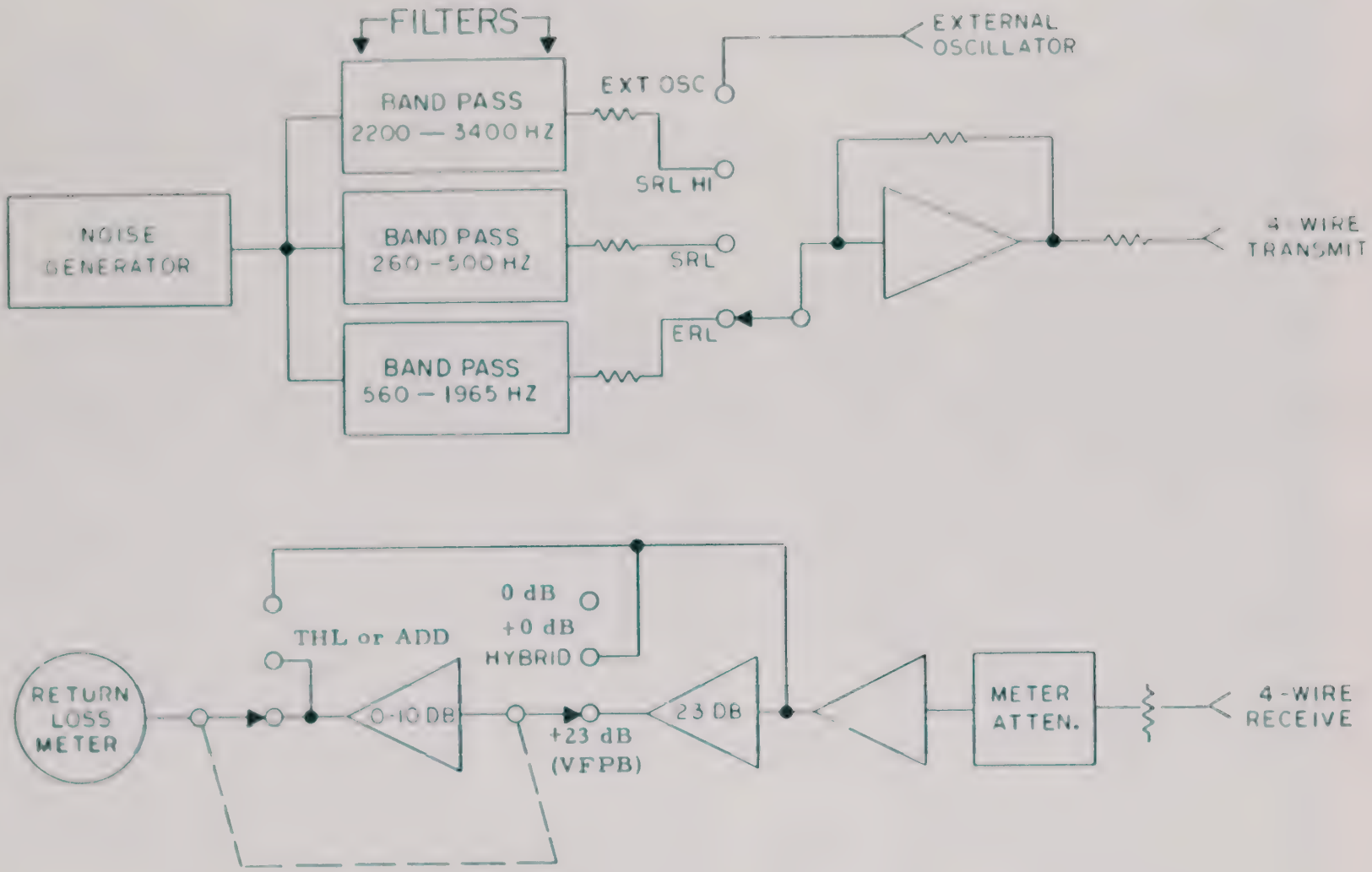


FIG. 1-E

4-WIRE LINE MEASUREMENTS

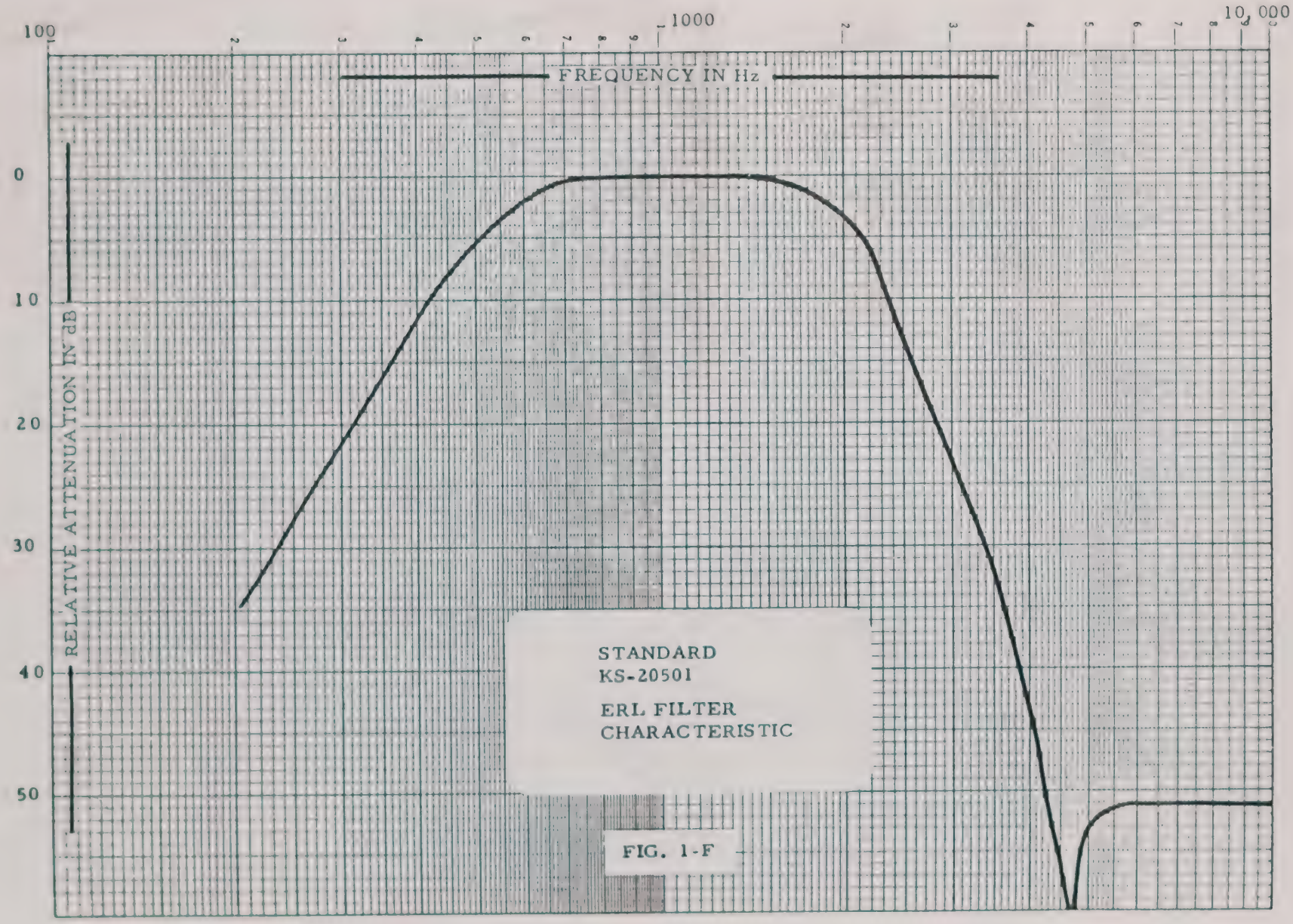

100
1000
10, 000
FREQUENCY IN Hz
0
10
20
30
40
50
RELATIVE ATTENUATION IN dB
STANDARD
KS-20501
ERL FILTER
CHARACTERISTIC

FIG. 1-F

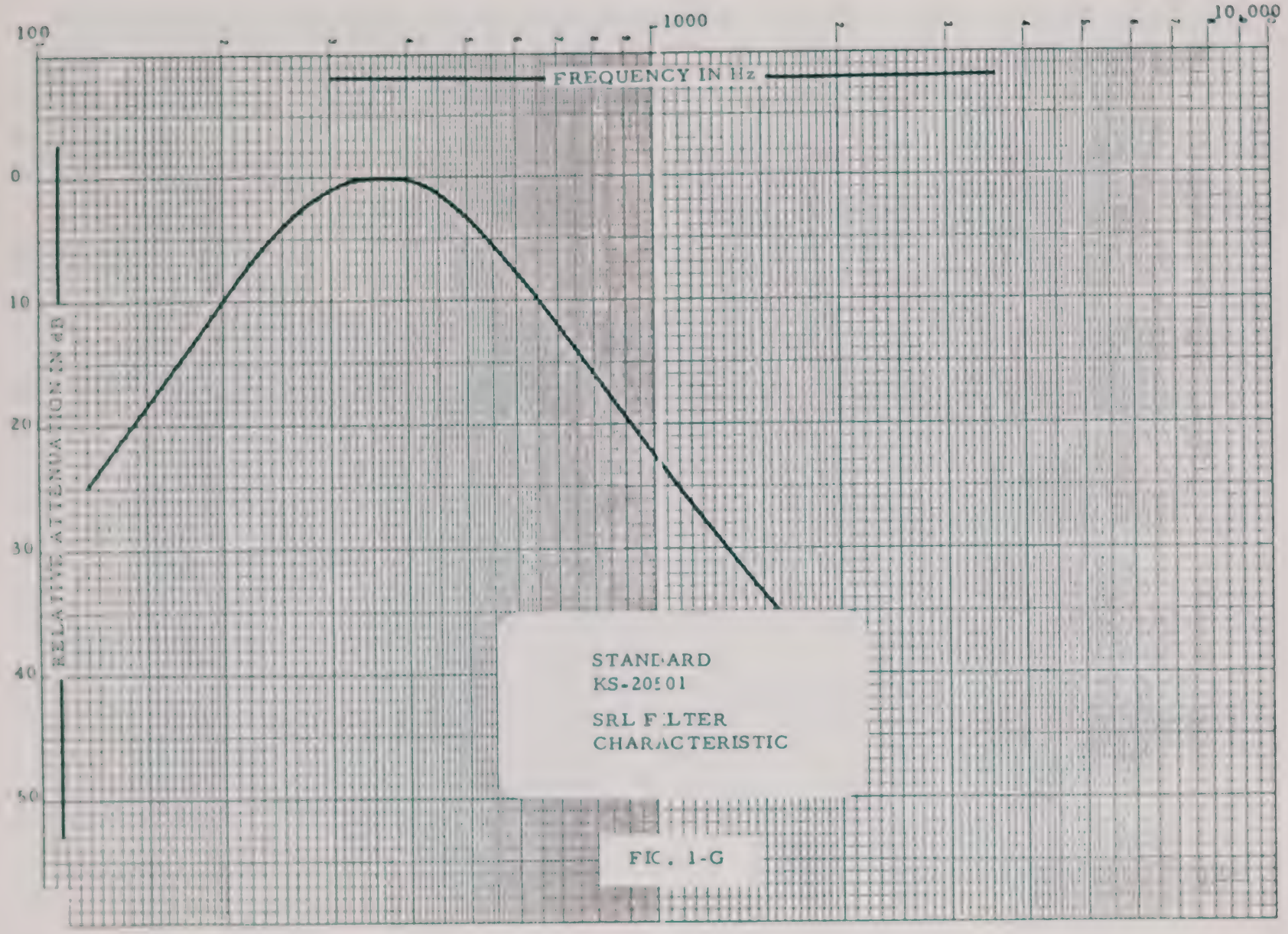

100
1000
10,000
FREQUENCY IN Hz
0
10
20
30
40
50
RELATIVE ATTENUATION IN dB
STANDARD
KS-20501
SRL FILTER
CHARACTERISTIC

FIG. 1-G

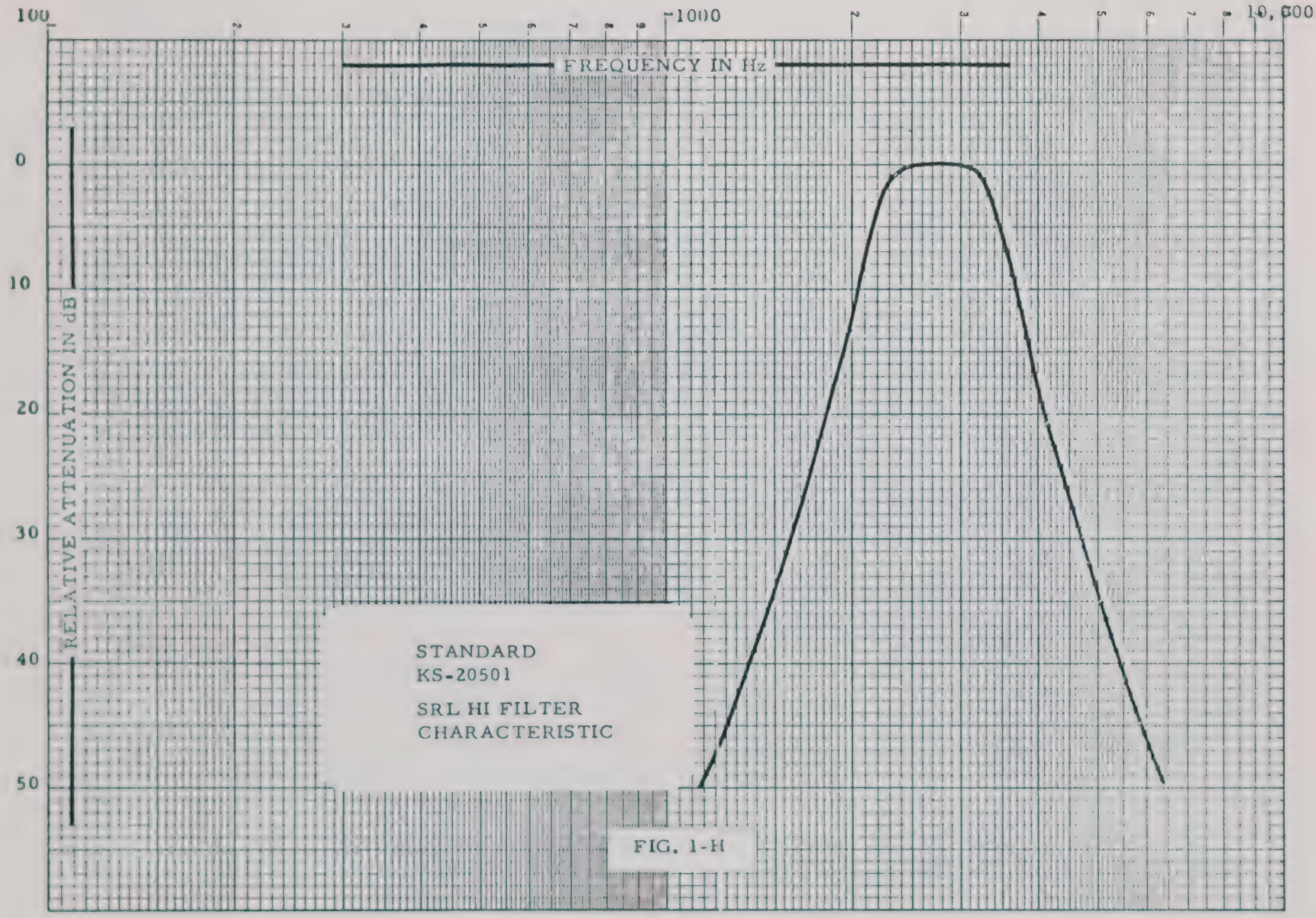

100
1000
10,000
FREQUENCY IN Hz
0
10
20
30
40
50
RELATIVE ATTENUATION IN dB
STANDARD
KS-20501
SRL HI FILTER
CHARACTERISTIC

FIG. 1-H

2.0 OPERATING INSTRUCTIONS

2.1 Controls, Jacks, and Meter

.1 TEST TYPE

This four-position switch allows selection of three internally generated signals or an externally connected oscillator test signal. The positions are designated ERL (Echo Return Loss), SRL (Singing Return Loss), SRL HI (Singing Return Loss High Frequency), and EXT OSC (External Oscillator).

.2 TEST LOCATION

On the KS-20501 L3&4 this control is a five-position switch to select the sensitivity and measurement configuration of the set. The positions are designated +23 dB, +0 dB, 0 dB, and 600, 900 (2-wire measurement). The KS-20501 L4 has the control as above, but without the 600, 900 (2-wire measurement) positions.

.3 NETWORK

This control is on the KS-20501 L3 set only, and is a two-position switch which selects between internal and external networks for 2-wire measurements. (Refer to Circuit Descriptions, Para. 3.2.7.) The positions are designated INT and EXT.

.4 THL OR ADD

These two rotary switches are used to adjust the sensitivity of both KS-20501 L3 and L4 sets to allow for losses in the measured circuit, which should not be included in the return loss measurement. One is a ten-position rotary switch which is marked from 0 dB to 10 dB in 1 dB increments, and the second is a five-position rotary switch in series with the first, marked from 0 dB to .8 dB in 0.2 dB increments. These two controls are bracketed with a dB indication and headed by the total THL OR ADD designation. A line running from THL OR ADD to +0 dB and +23 dB indicates their effect in these two TEST LOCATION positions.

.5 ADD dB

This five-position rotary switch is used in both the KS-20501 L3 and L4 sets to select signal level to the detector circuit to maintain the meter on-scale. The positions are designated -10, 0, +10, +20, +30, and when added to the meter indication it results in the return loss measurement. Negative numbers indicate return gain.

.6 PWR

This two-position toggle switch is used to connect and disconnect power to the circuits of both the KS-20501 L3 and L4 sets. The positions are designated ON, OFF.

.7 TRMT

These three jacks on the KS-20501 L3 provide access to the output test signal in the 4-W mode and are also used to connect the line under test in the 2-W mode. One jack accepts a WECO 310-type plug and is designated 310; the other two consist of black binding posts paired to accept a General Radio 938-type plug (or equivalent). One binding post is connected to the tip terminal of the 310 jack; the other is connected to the ring terminal of the 310 jack. The sleeve terminal of the TRMT jack is connected to the sleeve terminal of RCV jack. The KS-20501 L4 has rear terminal access to the output test signal.

.8 RCV

These three jacks on the KS-20501 L3 provide access for receiving the test signal from a 4-wire connection. One jack accepts a WECO 310-type plug and is designated 310; the other two consist of black binding posts paired to accept a General Radio 938-type plug (or equivalent). One binding post is connected to the tip terminal of the 310 jack; the other is connected to the ring terminal of the 310 jack. The sleeve terminal of the RCV jack is connected to the sleeve terminal of the TRMT jack. The KS-20501 L4 has rear terminal access for receiving the test signal.

.9 EXT OSC

These three jacks on the KS-20501 L3 provide access for using an external oscillator when measuring point-by-point return loss. One jack accepts a WECO 310-type plug and is designated 310; the other two consist of binding posts paired to accept a General Radio 938-type plug (or equivalent). The black binding post is connected to the tip terminal of the 310 jack; the natural metal binding post connects to the ring terminal and ground. There is no connection to the sleeve. These jacks are connected to the measuring portion of the set only when the TEST TYPE control is in the EXT OSC position. The KS-20501 L4 has rear terminal access to an external oscillator.

.10 EXT NET

These three jacks, on the KS-20501 L3 only, provide access for external network substitution when making 2-Wire measurements. One jack accepts a WECO 310-type plug and is designated 310; the other two consist of black binding posts paired to accept a General Radio 938-type plug (or equivalent). One binding post is connected to the tip terminal of the 310 jack; the other binding post is connected to the ring terminal of the 310 jack. The sleeve terminal has no connection. These jacks are connected to the measuring portion of the set when the NETWORK control is in either the EXT or INT position.

.11 RETURN LOSS dB

This meter is a linear movement, with a logarithmic electrically expanded scale of 0 to 10 dB in 0.5 dB increments and indicates an increasing return loss with an up-scale reading. It measures the total return loss when used in conjunction with the ADD dB control.

2.2 Procedures

.1 TEST LOCATION Selection

The first step in making a return loss measurement is a proper setting for the TEST LOCATION control selected from the following:

+23 dB - Used when testing at a voice frequency patch bay: provides a fixed 23 dB gain to compensate for the level difference plus an additional 10.8 dB of gain adjustable in 0.2 dB steps (THL) to compensate for line loss.

+0 dB - used when testing 4-wire terminating sets; allows for 10.8 dB gain, adjustable in 0.2 dB steps using the THL controls, to compensate for line and trans-hybrid loss.

0 dB - used when testing 4 wire circuits where no line loss compensation is necessary.

600-900 - used in 2-wire measurements.

.2 TEST TYPE Selection

The second step in making a return loss measurement is to determine the type of signal that will be used to stimulate the 2-wire or 4-wire line. The selection of the signal is accomplished by positioning the TEST TYPE control, on the front panel of the test set, to one of the following:

ERL - provides gaussian noise through a filter with 3 dB bandwidths of 560 to 1965 Hz.

SRL - provides gaussian noise through a filter with 3 dB bandwidths of 260 to 500 Hz.

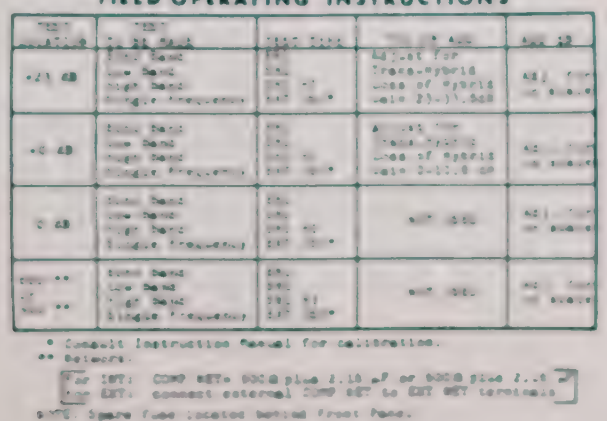
SRL HI - provides gaussian noise through a filter with 3 dB bandwidths of 2200 to 3400 Hz.

EXT OSC - allows for the use of an external oscillator with the signal injected at the EXT OSC terminals. Any signal with a frequency of 200 Hz to 15 kHz may be used. In this mode of operation, the AGC loop is not in effect; therefore, the output level of the transmitter must be controlled by the external oscillator.

NOTE: The approximate level for the external oscillator should be -3 dBm into 600 ohms, or about 0.55 V rms into the EXT OSC terminals.

.3 The following are the operating instructions as found in the cover of the portable test set.

RETURN LOSS TEST SET
FIELD OPERATING INSTRUCTIONS



* Consult Instruction Manual for calibration.
** Network.

For INT: COMP SET= 900Ω plus 2.16 μF or 900Ω plus 2.4 μF
For EXT: connect external COMP SET to EXT SET terminals

FUSE: Spare fuse located behind front panel.

2.2.4 2-Wire Return Loss Measurements

Set the TEST LOCATION control to either the 600 or 900 2-wire position as required. Select the desired signal using the TEST TYPE control. If the internal balancing network is to be used, the NETWORK control must be in its INT position; if an external network is to be used, the NETWORK control must be in its EXT position and a suitable network connected across the EXT NET terminals. The 2-wire line or unknown network to be measured is connected to the TRMT terminals. The ADD dB control is adjusted until the RETURN LOSS meter provides an on-scale indication. The indication of the RETURN LOSS meter in dB is added to the dB setting of the ADD dB control to give the total return loss.

Calibration is necessary with this test set only when the TEST TYPE control is in the EXT OSC position. Set TEST TYPE control in the EXT OSC position; the TEST LOCATION control in either 2-wire position; the NETWORK control in the INT position; no connection made to the TRMT terminals; the ADD dB control in the 0 position; adjust the external oscillator level control for a 0 dB indication on the RETURN LOSS meter. After this calibration is performed, any 2-wire measurement may be made as long as the external oscillator level remains constant. See 2.2.2 for external oscillator level.

.5 4-Wire Measurements

Select the desired signal using the TEST TYPE control.

The transmitting 4-wire line is connected to the TRMT terminals and the receiving 4-wire line is connected to the RCV terminals. If the +23 dB or +0 dB positions of the TEST LOCATION control are used, the known line loss correction should be inserted by adjusting the THL controls. Adjust the ADD dB control until an on-scale indication is obtained on the RETURN LOSS meter. The return loss is read directly by adding the meter dB indication to the ADD dB control indication.

As in the 2-wire mode, no prior calibration is necessary with this test set except when used in the EXT OSC position of the TEST TYPE control.

If an external oscillator is used, the calibration procedure for 4-wire measurements is as follows: with the TEST TYPE control set to the EXT OSC position; the external oscillator connected to the EXT OSC terminals; the TEST LOCATION control in the 0 dB position; the ADD dB control in the 0 position. Loop the TRMT terminals to the RCV terminals with a cable and adjust the external oscillator output level control for a RETURN LOSS meter indication of 0 dB. After this calibration is performed, any 4-wire measurement may be made as long as the external oscillator level remains constant. See 2.2.2 for external oscillator level.

2.3 Signal and Power Connections

.1 KS 20501 L3 Connections

Use connections as labelled on the front panel.

.2 KS 20501 L4 Connections

Pin designations are:

Signal	Pin No.
RCV	1 and 5
TRMT	4 and 8
Ground	6 and 7
-48V DC Input	2
Ext. Osc. Input	3

On the rear panel, a jack (J1 26-440-8P Amphenol) will receive a plug (P1 26-4501-8S Amphenol) which is furnished with the unit.

3.0 CIRCUIT DESCRIPTION

3.1 General

The list 3 and list 4 sets may be divided into two major sections - Transmitter and Receiver. The block diagrams (Fig. 3-A and Fig. 3-B) show the circuit functions which are described below. Both sets use the output of a broadband noise generator which is filtered in the transmitter section to provide the test signal. The output level is carefully regulated with an automatic gain control (AGC) loop. The receiver section of the block diagram shows the various gain controlling functions and the final detector and meter which provide a direct reading of return loss.

3.2 Transmitter

.1 Noise Generator (see page 6.2.12)

The white noise signal (dc to 300 kHz) voltage which is required to drive the shaping filters is produced by a Zener diode operating on the knee of its breakdown curve. This diode CR5 is biased between the ±12 volt supplies by resistors R89, R90, and R91. Capacitors C40 and C41 are used to decouple power supply ripple from the Zener diode. The output noise signal from the diode is coupled through capacitor C39 to the following stage.

.2 AGC Amplifier (6.2.12)

Integrated circuit amplifier A6 is driven directly from the output of the white noise source and is used to compensate for level variations. Amplifier A6 has a gain of approximately +30 dB to -60 dB and is operated at a nominal gain of 0 dB. The dc control input to A6 on terminal 2 ranges from 0 V dc to -6 V dc. At 0 V dc, A6 is operated at full gain and at -6 V dc it has maximum attenuation. The nominal operating dc voltage at terminal 2 is -3.3 V. Resistors R83, R84, R85, and R86 are used as voltage dividers to reduce the ±12 V supplies to the ±6 V nominal operating voltages for A6. Capacitors C37 and C38 are used as decoupling capacitors at the power supply inputs to A6. Resistors R88 and R87 are used to bias the inverting and non-inverting inputs to A6. Capacitor C36 is used to couple the output of A6 to the following stage. Amplifier A6 has a flat frequency response from 100 Hz to 1 MHz. The AGC circuit is in effect only when the internal filters are used. When the TEST TYPE switch is in the EXT OSC position, the feedback loop is broken and the output level stability of the transmitter is controlled by the external oscillator used.

.3 30 dB Wide Band Amplifier (6.2.12)

Integrated circuit operational amplifier A5 is used as a wide band (dc to 50 kHz) amplifier with approximately 30 dB of gain. Resistors R38, R39, R41, and R45 are used as a voltage divider to provide feedback from the output of A5 to its inverting input at terminal 3 to establish a gain of 25 dB. R46 is used to bias the non-inverting input terminal 4. Resistors R40, R42, and capacitors C18, C19, are used as frequency compensation networks. Resistors R43, R44, and capacitors C17, C20 are used as decoupling networks to the power supply inputs of A5.

3.2.4 Filters (6.2.5)

The three filters whose 3 dB bandwidths are 260 Hz to 500 Hz, 560 Hz to 1965 Hz, and 2200 Hz to 3400 Hz are made up of similar active circuits using only resistors and capacitors but no inductors. The input to the filters is a common line which is driven from the virtually zero ohm impedance of the 25 dB wide band amplifier.

260-500 Hz Filter: This band pass filter is made up of a separate low pass filter and high pass filter. The high pass section consists of a two-pole stage composed of capacitors C300, C301, resistors R300, R301, and transistors Q300, Q301. The active circuit, made up of transistors Q300 and Q301 is representative of the active circuits used throughout the three filters and will be described at this point.

Transistors Q300 and Q301 operate as a series-shunt feedback amplifier with unity gain high input impedance and low output impedance. Resistor R304 is used to establish the total dc current flowing through Q300 and Q301. Resistor R303 is used to establish the collector current of Q300. The base of Q300 is biased to ground through R302 and R301. R302 is used to suppress parasitic oscillations. Capacitor C303 is used to suppress closed loop oscillations. All the rest of the active circuits operate in the same fashion with the exception that the NPN and PNP transistors are interchanged so that the dc bias level may be maintained at approximately ground potential throughout the filters. The second stage of this high pass filter section is composed of capacitor C304 and resistor R305 (single pole) and transistors Q302 and Q303, therefore the total number of poles for this high pass section is three. The low pass portion of this filter is a two-pole stage of resistors R309, R310, with capacitors C306, C307, and transistors Q304, Q305. The single pole stage is made up of resistor R314 and capacitor C309 with transistors Q306 and Q307. Capacitor C350 is used to block dc from the output.

560-1965 Hz Filter: This filter is composed of high and low pass sections.

The high pass portion includes two stages. The first is a two pole stage made up of C311, C312, R319, R320, Q308 and Q309. The second, also a two pole stage, is made up of C314, C315, R324, R325, Q310, and Q311.

The low pass portion includes three stages. The first is a single pole stage made up of R330 and C318 in conjunction with Q312 and Q313. The second is a two pole stage comprising R334, R335, C320, C348, Q314, and Q315. The last is an active filter using an operational amplifier (CA3140). This circuit has a twin "T" notch at 4.7 kHz. Its null is determined by C401, C402, C403, R401, R402, and R407.

In order to maintain a transfer ratio of one across the filter, an attenuating network comprised of R408 and R410 brings the output through C409 to R109. R411 provides C409 a discharge path to ground.

2200-3400 Hz Filter: This filter is made up of separate high and low pass filters. Each contains three two pole stages, giving a total of six poles

.5 Output Amplifier (6. 2. 12)

Integrated circuit operational amplifier A3 is used as a dc to 20 kHz 25 dB gain amplifier. Resistors R68 and R70, in parallel with either R109, R110, R112, or R113, are used as a voltage divider between the output of A3 and the input signal to drive the inverting input, thereby establishing gain. Resistor R72 is used to bias the non-inverting input to A3. Resistors R67 and R69 and capacitors C25 and C26 are used as decoupling networks from the power supplies to A3. Since the output impedance of A3 is virtually zero ohms, parallel resistors R64 and R65 establish the proper source impedance to transformer T2.

.6 Dc Rectifier and Dc Amplifier (6 2. 12)

In order to provide dc control voltage for AGC amplifier A6, the ac output of A3 at the transformer T2 primary section is sampled through R66, converted to dc, and amplified. Diodes CR1 and CR2 and capacitors C28 and C29 form a voltage doubler rectifier which provides a dc input to amplifier A4 proportional to the ac output from the transformer. Integrated circuit operational amplifier A4 is used as a dc amplifier with differential inputs. The inverting input is provided by the dc reference voltage at the arm of potentiometer R74. Resistors R71, R76, R77, and R81 are used as voltage dividers to the inverting and non-inverting inputs of A4 to provide the differential gain of 40 dB. Capacitor C49 and resistor R79 are used to provide an extremely low frequency roll-off. Resistors R78 and R80 and capacitors C30 and C34 are used as decoupling networks to the power inputs to A4. Diode CR3 is used to compensate for the temperature coefficient of the diodes in the voltage doubler rectifier. Diode CR4 is used to prevent the input to A6 from becoming a positive voltage. Resistor R82 and capacitor C35 are used as a filter network to the input of A6. The operation of A4 is such that it provides a dc voltage to terminal 2 of A6 so that the gain of A6 is increased or decreased, maintaining the dc voltage at TP4 equal to the dc reference voltage at TP6. The dc reference voltage at TP6 being established from a highly stable source, the signal output of transformer T2 is held constant.

.7 Balancing Transformers and Hybrid (6. 2. 12)

The resistive hybrid used in the test set is composed of network arms

using capacitor C14 and resistor R32 or R33 and capacitor C16 with resistor R34 or R35, and with internal balancing networks made up of capacitor C15 and resistor R36 or R37. These internal networks are connected in the circuit when the front panel NETWORK switch is positioned at INT Transformers T1 and T2 are used to balance the hybrid network. The impedance seen looking into terminals 3 and 4 of transformers T1 and T2 is 600 ohms; therefore, when the TEST LOCATION switch is put on the 900 ohms position, two 150 ohm resistors R62 and R63 are placed in series with terminals 3 and 4 of T2 raising the input impedance to 900 ohms, likewise, two 150 ohm resistors R5 and R6 are placed in series with terminals 3 and 4 of T1 This must be done to properly drive and terminate the hybrid. Capacitors C1, C2 C21, and C22 are used to block dc currents from the test set. Varistors CR18 and CR19 are used to protect the transmit and receive circuits from high voltage ac signals (ringing). Capacitors C61 and C62 are used to compensate for the impedance of C21 and C22

Resistors R1-R2-R3-R4 form a 12 dB (2 dB for the L4) balanced pad which is used in the 4-wire mode to duplicate the trans hybrid loss in the 2-wire mode.

3.3 Receiver

.1 Meter Attenuator (ADD dB) and Amplifier (6.2 12)

Resistors R8 through R16 form a five-position attenuator with four 10 dB steps. The front panel indication is used in conjunction with the meter indication to determine return loss.

Integrated circuit operational amplifier A1 is used as a dc to 20 kHz 55 dB (45 dB for the L4) amplifier. Resistors R18, R19, R22, and R23 form a voltage divider between the output of A1 and the inverting input to establish gain. Resistor R17 provides the bias for the non-inverting input. Resistors R20 and R21 and capacitors C6 and C7 are used as decoupling networks to the power supply inputs.

.2 THL Correction Amplifier and Pads (6.2.12)

Integrated circuit operational amplifier A2 is connected as a non-inverting 23-33.8 dB gain amplifier. Resistors R27, R28, R47 through R61, and R31 form a switchable voltage divider network to adjust the gain of the amplifier. Resistors R47 through R50 control the gain in 0.2 dB steps and resistors R52 through R61 control the gain in 1.0 dB steps. Resistor R26 is used to provide the input bias to the non-inverting input (as well as being part of the input attenuator). Resistors R29 and R30 and capacitors C12 and C13 are used as decoupling networks to the power supply inputs. Resistors R116 and R26 are used to provide 3.5 dB loss with switch S2 in the +23 dB position. Resistors R24 and R26 are used to provide 26.5 dB loss with switch S2 in the +0 dB position.

3. 3. 3 Meter Driver Amplifier (6. 2. 12)

Integrated circuit operational amplifier A7 is connected as an ac amplifier with a full wave bridge rectifier network and dc meter in its feedback network. The output of A7 (terminal 3) drives a full wave bridge rectifier composed of CR6, CR9, CR12, and CR13. The positive output of this bridge is established at the junction of CR6 and CR12. The current established due to the rectifier drives the dc meter up-scale left via R11[illegible] through R12[illegible]. A reversed bias to the meter allows the expanded signal characteristic controlled by the resistor-diode network, which consists of resistors R100-R101-R102-R103-R105-R106-R107-R108 and diodes CR14-CR15, CR16-CR17. Diode CR15 is a 10 V Zener diode which establishes a stable reference potential while diodes CR14, CR16, and CR17 are used for temperature compensation of the reference voltage. Diodes CR7 and CR8 are used to prevent the meter from being overloaded. Capacitors C43 and C52 filters the random noise signal being measured, minimizing the fluctuations of the meter. The balance of the feedback network to amplifier A7 is composed of resistors R93 and R94. Adjustment of R94 controls the forward current through the meter and adjustment of R103 controls the reverse bias current through the meter. Resistors R95 and R99 and capacitors C46 and C47 are used as decoupling networks to the power supply inputs. Resistor R92 is used to provide the bias to the non-inverting input to A7.

3. 4 Power Supplies

. 1 Ac Input Power Supply (6. 2. 8)

This power supply is used to provide filtered and regulated +12 V and -12 V for internal test set operation from a main supply of 115 V ±10%, 60 Hz ac. This circuit is composed of a power cord input, line fuse, line power switch, and center tapped step-down transformer T201. T201 drives a full wave bridge rectifier assembly which provides positive 20 V dc to TP204 and negative 20 V dc at TP205. Capacitors C206 and C209 are filters for the full wave dc provided by the rectifier assembly CR201.

+12 Volt Regulator

The +12 volt regulator is composed of series pass transistor Q204, amplifier transistor Q205, and voltage reference diode CR205. The 12 V dc output voltage is established by summing up the reference voltage of CR205, the Vbe potential of Q205, and the forward bias potentials of CR203 and CR204. Resistors R210 and R211 provide base current for Q204 and collector current for Q205. Capacitor C207 further removes the ripple from the current through R210 and R211. Resistor R215 establishes the proper bias current for Zener diode CR205.

If the voltage at TP208 attempts to rise, since there is a constant voltage drop across CR205, the base voltage of Q205 will rise, increasing its base current. This increase in base current will increase its collector current. The total current through R211 is made up of the base current through Q204 and the collector current of Q205; therefore, an increase in the collector current of Q205 will decrease the base current of Q204 while the current through R211 remains constant. A decrease in base current of Q204 will decrease its emitter current, reducing the current through the load, which will tend to reduce the voltage at TP208 and achieve the regulating action.

Diodes CR203 and CR204 and the base emitter junction of Q205 serve to compensate the temperature coefficient of CR205.

-12 Volt Regulator

The -12 volt regulator consists of series pass transistor Q207 and amplifier transistor Q206. Resistors R212 and R213, with capacitor C210, provide filtered current for the base of Q207 and the collector of Q206. The voltage divider composed of R216 and R217 is designed to establish a negative 0.7 V dc potential at TP209 when there is positive 12 V dc at TP208 and negative 12 V dc at TP210.

The action of the -12 V regulator is similar to the +12 V regulator except that the voltage at TP209 is used as the reference. The action of this regulator is such that the negative voltage will track the absolute value of the positive voltage regulator with a negative potential. For example, if the positive voltage output were to become +12.5 V, then the negative output voltage would be -12.5 V. Effectively, the positive voltage regulator establishes the voltage control and the negative regulator merely tracks in the opposite polarity.

.2 -48 Volt Input Power Supply (6.2.11)

The purpose of this circuit is to provide ±12 V dc with respect to ground from a -48 V dc input supply having a positive ground. The ground of the ±12 V supply is common to the positive ground of the -48 V input supply.

Switch S1 is the front panel PWR switch.

Diode CR208 protects the power supply against reversed polarity of the 48 V supply during installation. A low pass "pi" filter composed of capacitors C211, C212, C213 and inductor L200 attenuates high frequency noise generated in the power supply to minimize the amount transferred back to the -48 V supply.

Unijunction transistor Q200 and transistor Q201 form an astable multivibrator operating at approximately 200 Hz. Resistors R201 and R204 and capacitor C201 form a voltage divider to provide filtered -28 V (with

respect to ground) at their common junction. The operation of the astable multi-vibrator is as follows: assuming that the emitter of unijunction Q200 is non-conducting and transistor Q201 is conducting, the potential at TP201 will be at -47.3 V dc. Capacitor C202 will charge through resistor R203. The voltage at TP200 increases until the unijunction fires and the voltage at TP200 abruptly returns to -47 V. At the instant the unijunction fires, the voltage at TP201 goes negative with respect to the emitter of Q201, turning off Q201. When Q201 turns off, its collector voltage switches to ground potential. At this time, C202 charges through R205 and the emitter of Q200 until the potential at TP201 is positive with respect to the emitter of Q201. At this point, Q201 turns on and its collector voltage switches to -48 V. The time constants of this circuit are selected to provide a square wave with a 200 Hz repetition rate and a 50% duty cycle.

The collector voltage of Q201 is used to drive a pair of transistors used as a complementary switch. When the potential at TP202 is at -48 V, Q202 is non-conducting and Q203 is saturated. This action provides a 48 V peak to peak square wave, driven from a very low impedance source at TP 203. The square wave at TP203 is coupled through capacitor C205, diodes CR201, CR202, and filter capacitors C206, C209, to provide +24 V dc at TP204 and -24 V dc at TP205.

Zener diode CR206 is used to prevent TP204 from going more positive than +22 V. Zener diode CR207 is used to prevent TP205 from going more negative than -22 V.

The operation of the ±12 V regulators is the same as that of the AC Input Power Supply.

3.5 Circuit Differences, L3 and L4 Sets

.1 Inputs

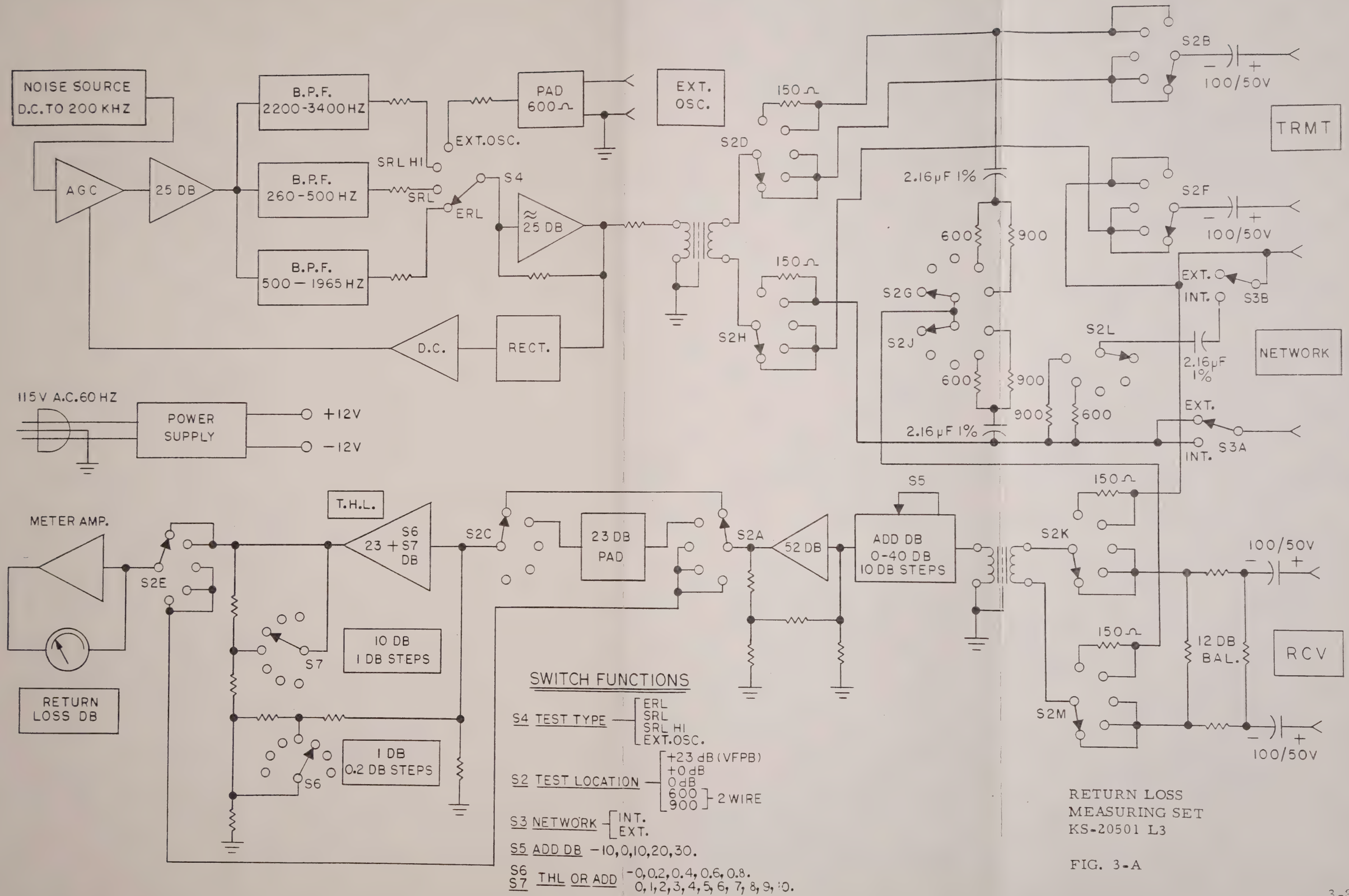
Any connection made to external lines or equipment on the L3 test set is made at the front panel by way of a 310-type telephone jack or General Radio-type binding post.

All external connections to the L4 test sets are made by way of a rear panel cable connector. (See Par. 2.3.2.)

.2 Power Supplies

The internal power supply for the L3 test set is powered from the external 115 V rms 60 Hz power mains through a power cord extending from the front panel.

The internal connections to the L4 test set power supply are powered from an external -48 V dc supply. The power input to the unit is made by the means of the rear cable connector. (See Par. 2.3.2.)



SWITCH FUNCTIONS

S4 TEST TYPE — ERL, SRL, SRL HI, EXT.OSC.

S2 TEST LOCATION — +23 dB (VFPB), +0 dB, 0 dB, 600 2 WIRE, 900 2 WIRE

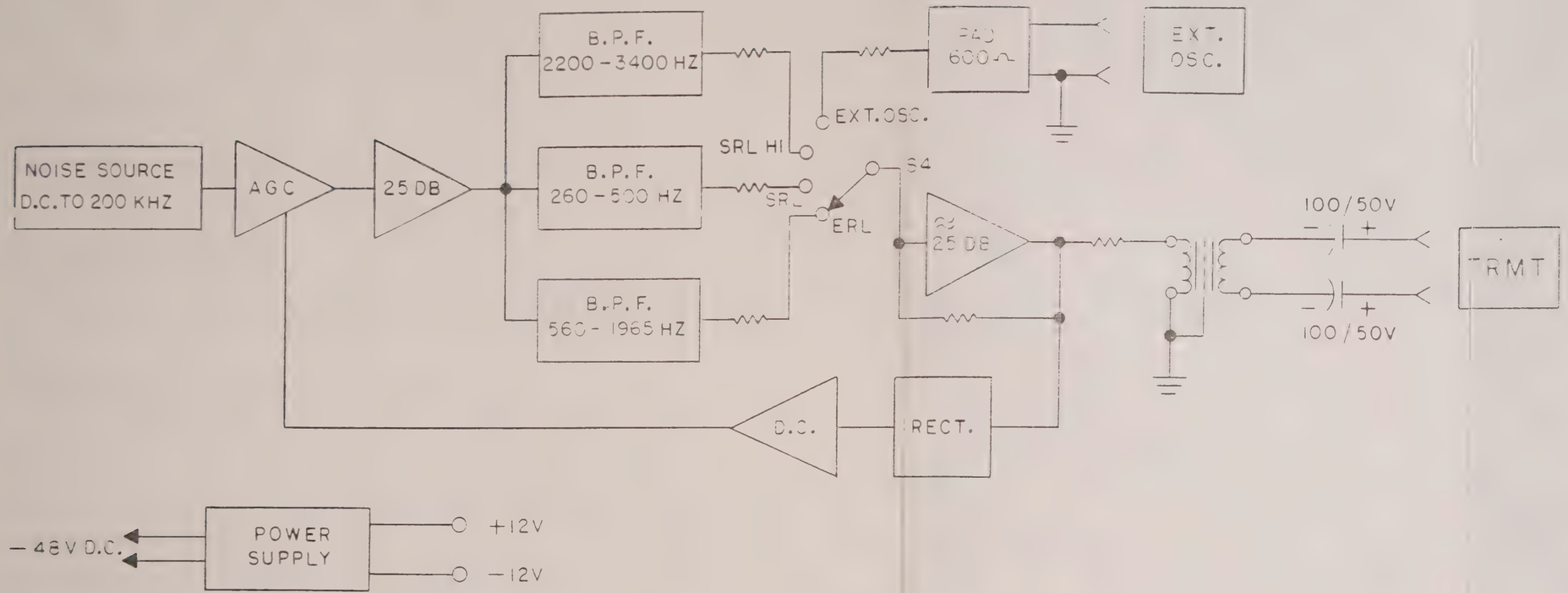
S3 NETWORK — INT., EXT.

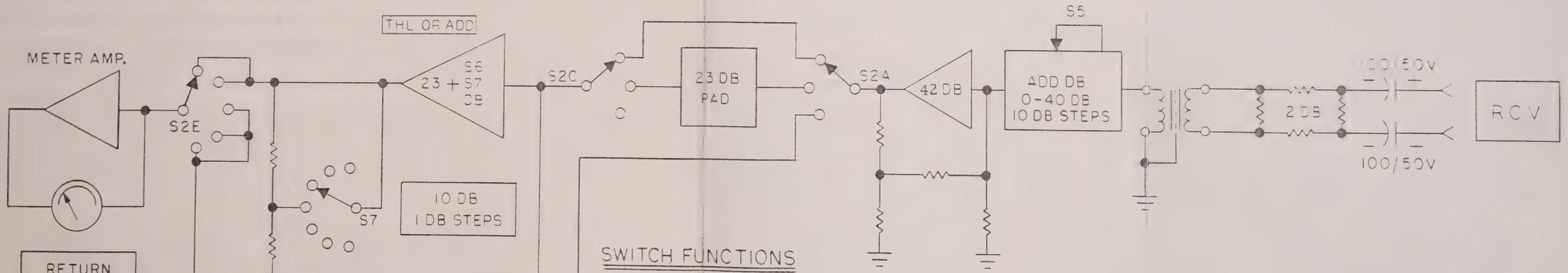
S5 ADD DB — −10, 0, 10, 20, 30.

S6 S7 THL OR ADD — −0, 0.2, 0.4, 0.6, 0.8. 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10.

RETURN LOSS
MEASURING SET
KS-20501 L3

FIG. 3-A





SWITCH FUNCTIONS

S4 TEST TYPE — ERL, SRL, SRL HI, EXT. OSC.

S2 TEST LOCATION — +23 DB, +0 DB, 0 DB

S5 ADD DB — -10, 0, 10, 20, 30.

S6, S7 THL OR ADD — 0, 0.2, 0.4, 0.6, 0.8; 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

RETURN LOSS
MEASURING SET
KS-20501 L4

FIG. 3-B

4.0 MAINTENANCE

4.1 Introduction

This section contains maintenance and service information for the KS-20501 L3 and L4 Return Loss Measuring Sets: Performance Checks, and Calibration and Adjustment Procedures, are included.

4.2 Test Equipment Required

The test equipment required for maintenance of the Return Loss sets is outlined in Table I; listed are the types of equipment to be used, the critical specifications, and the recommended commercially available units.

4.3 Cabinet Removal

.1 To remove the L3 Test Set from its case:

.a Turn the PWR switch to OFF and disconnect the power cord from the power source.

.b With the unit in the normal operating position, remove the cover, unwind the power cable, loosen the four #10 oval slotted captive screws until the panel is free from the case.

.c Turn the instrument upside-down on a padded surface; then lift the case from the electronics portion (front panel).

.d Reverse the procedure to replace the case.

.2 To remove the L4 Test Set from its dust cover, remove the six No. 6 slotted captive screws.

4.4 Performance Checks

The performance checks are to be performed with the Return Loss Test Sets in the case (L3) or the dust cover (L4). These procedures are designed to be used for periodic maintenance, incoming quality control checks, and to check specifications after a repair.

CAUTION

When replacing the power cable in the cover of the portable set, take care that the three-prong plug is first placed under the left retaining tab before completely winding the cord so as to prevent a possible jamming of controls.

TEST EQUIPMENT REQUIRED

INSTRUMENT TYPE	REQUIRED CHARACTERISTICS	USE	RECOMMENDED MODEL
RMS Voltmeter	Frequency Range: 10 Hz to 10 MHz Accuracy: ± 1% 50 Hz to 1 MHz Voltage Input: 0.001 to 300 V	Output Level	Hewlett-Packard 3400A
Wave Analyzer	Frequency Range: 20 Hz to 50 kHz Band Width: 10 Hz Accuracy of Calibration: ± 1/2% +5Hz	Filter Characteristics	General Radio 1900-A
Audio Oscillator	Frequency Range: 5 Hz to 600 kHz Impedance: 600 Ω Max. Distortion: 0.2% 20 Hz to 200 kHz	External Oscillator Frequency Response Receiver Sensitivity Receiver Frequency Response Longitudinal Balance Filter Characteristic Check ERL, SRL, SRL HI Filter Adj. Output Impedance Adj. Input Impedance Adj. Meter Sensitivity Adj.	Hewlett-Packard 200CD
Vacuum Tube Voltmeter	Accuracy: within ± 1% of full scale Meter: linear expanded dB scale Calibration: 1 mW in 600 Ω	External Oscillator Frequency Response Receiver Sensitivity Receiver Frequency Response Longitudinal Balance Filter Characteristic Check ERL, SRL, SRL HI Filter Adj. Output Impedance Adj. Input Impedance Adj. Meter Sensitivity Adj.	Hewlett-Packard 400L

Attenuator Set	Range: 0-111 dB in steps of 0.1 dB Accuracy: within 0.1 ± 1% dB at 1 kHz Impedance: 600 Ω	Receiver Sensitivity Filter Characteristics ERL, SRL, SRL HI Filter Adj. Meter Sensitivity Adj.	General Radio 1450-TBR
Voltmeter	Range: 5000 V rms 5000 V dc Accuracy: ± 2% V dc full scale ± 3% V ac full scale	Power Supplies Check	Simpson 260
Digital Frequency Counter	Frequency Range: DC to 32 MHz Accuracy: ± 0.3%	Filter Characteristic Check ERL, SRL, SRL HI Filter Adj.	General Radio 1192
Oscilloscope	Band Width: DC to 13 MHz Rise Time: 27 ns	Waveforms	Tektronix 531A CA Dual Trace Plug-In
0.05 μF capacitor	Accuracy: measured to ± 1% absolute	Network	
2.16 μF capacitor	Accuracy: ±1%	Accuracy 2-Wire	
Balancing Transformer		Longitudinal Balance	UTC A20
900Ω resistor	Accuracy: ±1%	Terminating Load	RN65C9000F
600Ω resistor	Accuracy: ±1%	Terminating Load	RN65C6000F
150Ω resistor	Accuracy: ±1%	Network	RN65C1500F
150Ω resistor	Accuracy: ±5%	Balance	RC20GF151J
Adapter	GR double-plug	Network	General Radio Type 274-MB
Test Leads	GR to GR, 24" L. GR to alligator, 24" L.		
900 Ω resistor	Accuracy: ± 0.1%	Network	

TABLE I

4.4 Performance Checks (Continued)

.1 Output Level

.a A true rms ac voltmeter, such as a Hewlett-Packard 3400A, a 900 Ω ± 1% resistor, and a 600 Ω ± 1% resistor are needed for this test.

.b Set TEST LOCATION switch to 0 dB and TEST TYPE switch to ERL.

.c Connect the 600 Ω resistor and the ac voltmeter across the TRMT terminals of the Test Set.

.d The average reading of the voltmeter, set to maximum damping, should be -2 dBm ± 0.2 dB.

.e Set TEST TYPE switch to SRL; the as voltmeter should read -2 dBm ± 0.2 dB.

.f Set TEST TYPE switch to SRL HI; the ac voltmeter should read -2 dBm ± 0.2 dB.

.g Set TEST LOCATION switch to 600 Ω and TEST TYPE switch to ERL, and replace the 600 Ω resistor across the TRMT terminals with the 900 Ω resistor; the ac voltmeter shall read -8 dBm ± 0.2 dB (assuming the voltmeter scale is calibrated for 600 Ω and 1 mW).

.2 Filter Characteristics

.a A wave analyzer, such as a General Radio 1900-A, with a 10 Hz measurement band width, and a 600 Ω ± 1% resistor are needed to perform this test.

.b Set TEST LOCATION switch to 0 dB and TEST TYPE switch to ERL.

.c Connect the wave analyzer input terminals and the 600 Ω resistor to the Test Set TRMT terminals.

.d Using the ERL filter characteristic as a guide, sweep the frequency band from 80 Hz to 5 kHz with the wave analyzer. Compare the resulting relative frequency characteristic with the ERL filter curve, FIG. 1-F. The two should be approximately the same. This is intended as a guide test since the analyzer is difficult to read when monitoring a gaussian noise signal. A more accurate check can be made by following the procedure given in the Calibration section.

.e Set TEST TYPE switch to SRL; repeat the spectrum measurement. Compare the result with the SRL HI filter characteristic in FIG. 1-H.

.3 EXT OSC Frequency Response

.a An audio oscillator, such as a Hewlett-Packard 200 CD, a VTVM such as a Hewlett-Packard 400 L, and a 600 Ω ± 1% resistor are needed for this measurement.

4.4.3.b Set TEST LOCATION switch to 4-XB and TEST TYPE switch to EXT OSC.

.c Connect the audio oscillator to the EXT OSC terminals and the 500 Ω resistor and a VTVM across the TRMT terminals.

.d Set the oscillator output level to obtain a reading of 0 dB on the VTVM. Vary the oscillator frequency from 100 Hz to 15 kHz while checking to see that its output level is constant.

.e The maximum amplitude excursion at the TRMT terminals should not exceed .4 dB from 200 Hz to 5 kHz and 1 dB from 100 Hz to 15 kHz.

.4 Receiver Sensitivity

.a A VTVM, such as a Hewlett-Packard 400 L, an audio oscillator, such as a Hewlett-Packard 200 CD, and an attenuator, such as a General Radio 1450-TBR, will be needed for this test. Connect the test equipment to the Test Set RCV terminals as shown in FIG. 4-A.

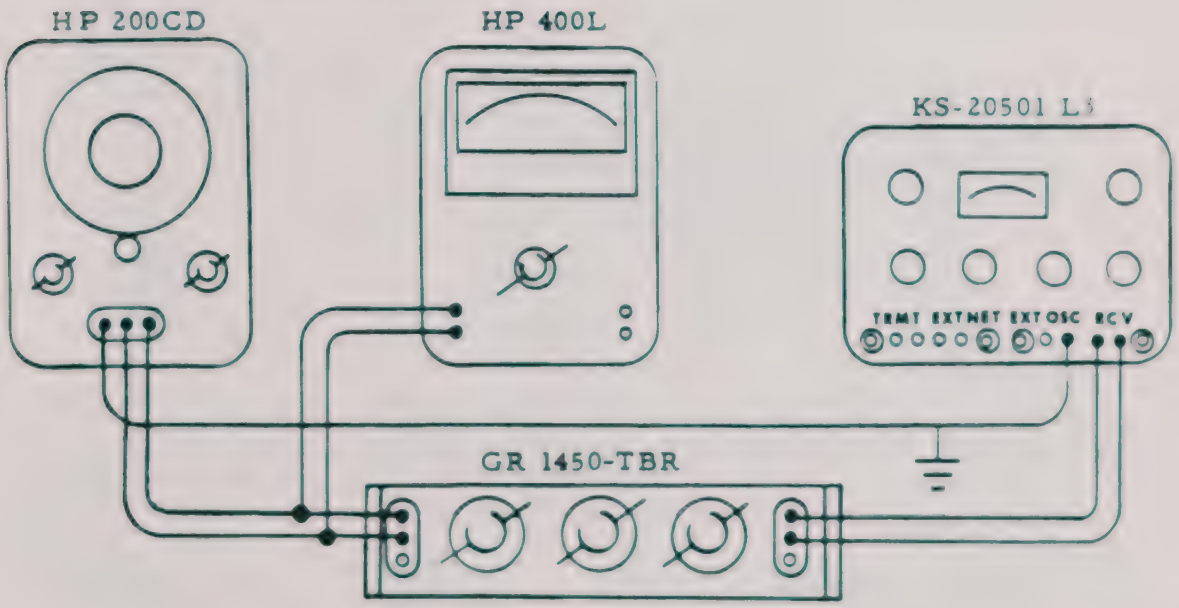


FIG. 4-A

NOTE: Test Set should be grounded to signal source through EXT OSC ground terminals.

.b Set TEST LOCATION switch to +0 dB, THL switch to 10.0 dB, and ATTN dB switch to -10.

.c With the attenuator set to 0 dB, adjust the audio oscillator output level (at 1 kHz) to obtain a Test Set RETURN LOSS dB meter indication of 0 dB. (Approximately -3 dBm output from the oscillator.)

4.4.4.d Set the Test Set and test equipment controls as shown in the following table. In each case the RETURN LOSS dB meter reading should be 0 ±0.1 dB.

TEST LOCATION	ADD dB	THL OR ADD 1 dB	THL OR ADD 0.2 dB	ATTENUATOR
+0 dB	-10	10	0	0.0
+0 dB	0	10	0	10.0
+0 dB	10	10	0	20.0
+0 dB	20	10	0	30.0
+0 dB	30	10	0	40.0
+0 dB	30	9	0	39.0
+0 dB	30	8	0	38.0
+0 dB	30	7	0	37.0
+0 dB	30	6	0	36.0
+0 dB	30	5	0	35.0
+0 dB	30	4	0	34.0
+0 dB	30	3	0	33.0
+0 dB	30	2	0	32.0
+0 dB	30	1	0	31.0
+0 dB	30	0	0.2	30.2
+0 dB	30	0	0.4	30.4
+0 dB	30	0	0.6	30.6
+0 dB	30	0	0.8	30.8
0 dB	30	0	0	30.0
+23 dB	30	0	0	53.0

.e Set TEST LOCATION switch to 0 dB and ADD dB switch to 0. Set the attenuator 10.0 ±0.1 dB with the audio oscillator referenced 1 kHz and level adjusted to obtain a 0 dB reading on the RETURN LOSS dB meter. Adjust the attenuator to obtain the required meter indication in the table below.

ATTENUATOR	RETURN LOSS dB Meter	ATTENUATOR	RETURN LOSS dB Meter
10.5	0.5	15.5	5.5
11.0	1.0	16.0	6.0
11.5	1.5	16.5	6.5
12.0	2.0	17.0	7.0
12.5	2.5	17.5	7.5
13.0	3.0	18.0	8.0
13.5	3.5	18.5	8.5
14.0	4.0	19.0	9.0
14.5	4.5	19.5	9.5
15.0	5.0	20.0	10.0

4.4.5 Receiver Frequency Response

.a An audio oscillator, such as a Hewlett-Packard 200 CD, and a VTVM such as a Hewlett-Packard 400 L, will be needed for this test.

.b Connect the oscillator and VTVM to the RCV terminals of the Test Set.

.c Set TEST LOCATION switch to 0 dB and ADD dB switch to 0.

.d Adjust the oscillator output level to provide an indication on the RETURN LOSS dB meter of 0 dB. (Approximately -3 dBm output from the oscillator at 1 kHz.)

.e Sweep the oscillator frequency from 100 Hz to 15 kHz and adjust the oscillator output level to keep the RETURN LOSS dB meter indication at 0 dB. Note the excursions of the oscillator output on the VTVM.

.f The maximum excursion (from maximum to minimum) of the oscillator output level shall be 0.4 dB from 200 Hz to 5 kHz; 1 dB from 100 Hz to 15 kHz.

.4 Longitudinal Balance

.a A VTVM, such as a Hewlett-Packard 400 L, an audio oscillator, such as a Hewlett-Packard 200 CD, a balancing transformer, such as a U.T.C. Model A20, and a 150 Ω ±5% resistor are needed for this test.

.b Connect the Test Equipment as shown in FIG. 4-B.

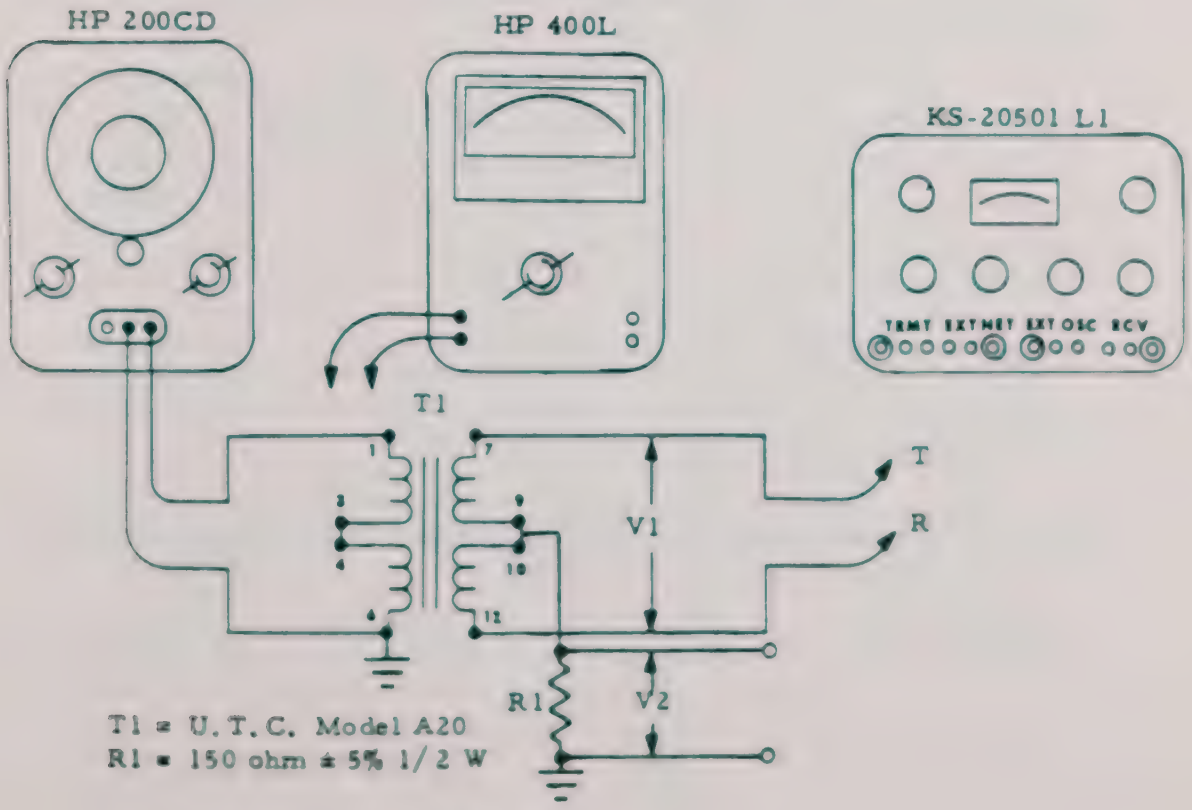


FIG. 4-B

4.4.6.c The longitudinal balance measurements are made by connecting the test circuit T and R terminals to the proper terminals of the Test Set; connect the VTVM across T and R to measure V_1 (150Ω resistor should not be grounded when measuring V_1; adjust the oscillator output level to obtain 0 dBm at V_1; remove the VTVM from V_1 and connect it to measure V_2. The absolute value of the voltage measured at V_2 in dB is the longitudinal balance at the frequency used; e. g. , V_2 = -65 dB, therefore balance = 65 dB.

.d Connect the T and R terminals of the test circuit to the TRMT terminals of the Test Set.

.e Set TEST LOCATION switch to 0 dB, TEST TYPE switch to EXT OSC, NETWORK switch to INT, and ADD dB switch to 0. Perform the longitudinal balance measurements at 100 Hz and 3000 Hz. The balance shall be greater than 70 dB at 100 Hz and 55 dB at 3000 Hz. Repeat these measurements with the TEST LOCATION switch in the 600 Ω and 900 Ω positions.

.f Set the TEST LOCATION switch to the 0 dB position and connect the T and R terminals of the test circuit to the RCV terminals of the Test Set. Repeat the measurements of the preceding paragraph.

.7 Hybrid Check (L3 only)

.a Set TEST LOCATION switch to 600 Ω, TEST TYPE switch to ERL, NETWORK switch to INT, and ADD dB switch to 0. The RETURN LOSS dB meter should indicate 0 ±0.2 dB.

.b Connect a shorting strap across the TRMT terminals or use a shorting type plug in the 310 jack. The RETURN LOSS dB meter should indicate 0 ±0.2 dB.

.c Set TEST LOCATION switch to 900 Ω. The RETURN LOSS dB meter should indicate 0 ±0.2 dB.

.d Remove the short from the TRMT terminals or the 310 jack. The RETURN LOSS dB meter should indicate 0 ±0.2 dB.

.8 Accuracy of 2-W Measurements (L3 only)

.a A 900 Ω ±0.1% resistor and a network composed of a 900 Ω ±0.1% resistor in parallel with a 0.05 μF ±1% capacitor will be needed for this test.

.b Set NETWORK switch to INT.

.c The test network is connected to the TRMT terminals and the Test Set is operated as shown in the following table. All Return Loss readings should be ±0.4 dB of those shown on the table.

TEST LOCATION	TEST TYPE	Test Network	Return Loss-dB
900	ERL	900 Ω	28.3
900	ERL	900 Ω//.05 μF	15.7
900	SRL	900 Ω	18.9
900	SRL	900 Ω//.05 μF	23.1
900	SRL HI	900 Ω	36.6
900	SRL HI	900 Ω//.05 μF	8.9

4.4.9 Accuracy of 2-W Measurements (L2 only)

.a Four 900 Ω ± 0.1% resistors, four 150 Ω ± 1% resistors, three 2.16 μF ± 1% capacitors, and one 2.05 μF ± 1% capacitor will be needed for this test.

.b A Test Hybrid is composed of three 900 Ω resistors and three 2.16 μF capacitors, as shown in FIG. 4-C.

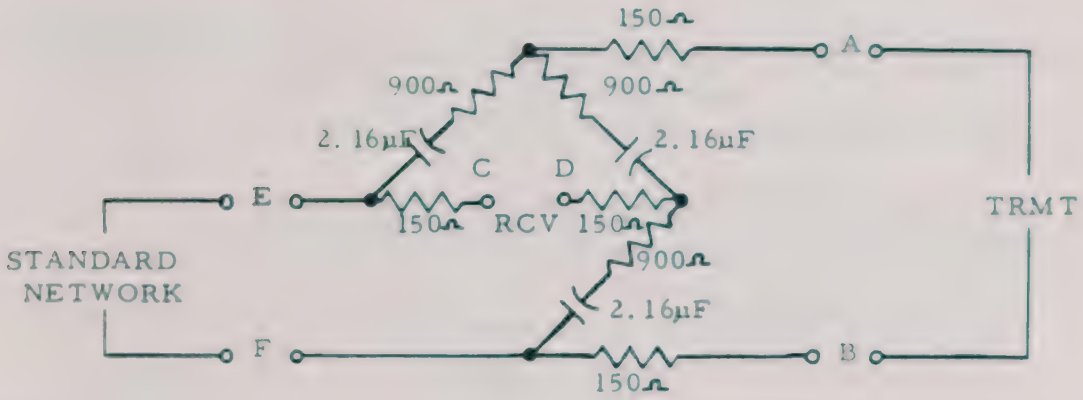


FIG. 4-C

.c Connect the Transmit terminals to A and B; the Receive terminals to C and D.

.d Set TEST LOCATION switch to +0 dB, THL switch to 10.0 dB, and TEST TYPE switch to ERL.

.e Without the Test Standard Network connected to the Test Hybrid, the Test Set should read approximately 8 dB. Note the actual reading of the Test Set as this will be used as a reference.

.f Connect the Standard Network (composed of either a 900 Ω resistor or a 900 Ω resistor in parallel with a 0.05 μF capacitor) to terminals E and F of the Test Hybrid and note the Test Set reading. The difference between this reading and the reference reading taken in the preceding step is the return loss.

.g Repeat the test for the conditions shown in the following table. The return loss indicated on the Test Set should be within ±0.4 dB.

TEST LOCATION	TEST TYPE	THL OR ADD	Return Loss-dB
+0 dB	ERL	10.0	28.3
+0 dB	ERL	10.0	15.7
+0 dB	SRL	10.0	18.9
+0 dB	SRL	10.0	23.1
+0 dB	SRL HI	10.0	36.6
+0 dB	SRL HI	10.0	8.9

4.5 Calibration and Adjustment Procedures

Remove the Return Loss Test Set from the carrying case (L3) or from the dust cover (L4) as instructed in Section 4.3 The calibrations are performed with the instruments powered in the following manner: the L3 portable model from a power source of 115 V, 60 Hz; the L4 rack mount model from a -48 V dc source with connection made through the rear cable connector.

.1 Power Supply

A check of the +12 V and -12 V supplies for nominal value will suffice. A voltmeter, such as the Simpson 260, and a pair of alligator clip leads about 24 inches long will be required for this testing.

.2 +12 Volt Supply Check

Connect the dc voltmeter to test point TP208 and the common lead to the chassis. The voltmeter should read +12.0 ±.70 V.

.3 -12 Volt Supply Check

Connect the dc voltmeter to test point TP210 and the common lead to the chassis. The voltmeter should read -12.0 ±.70 V.

.4 Filter Characteristics Check

An audio oscillator, such as a Hewlett-Packard 200CD, an attenuator, such as a General Radio 1450-TBR, a VTVM, such as a Hewlett-Packard 400L, and a digital frequency counter, such as a General Radio 1192, will be required to measure the filter characteristics. See FIG. 4-D.

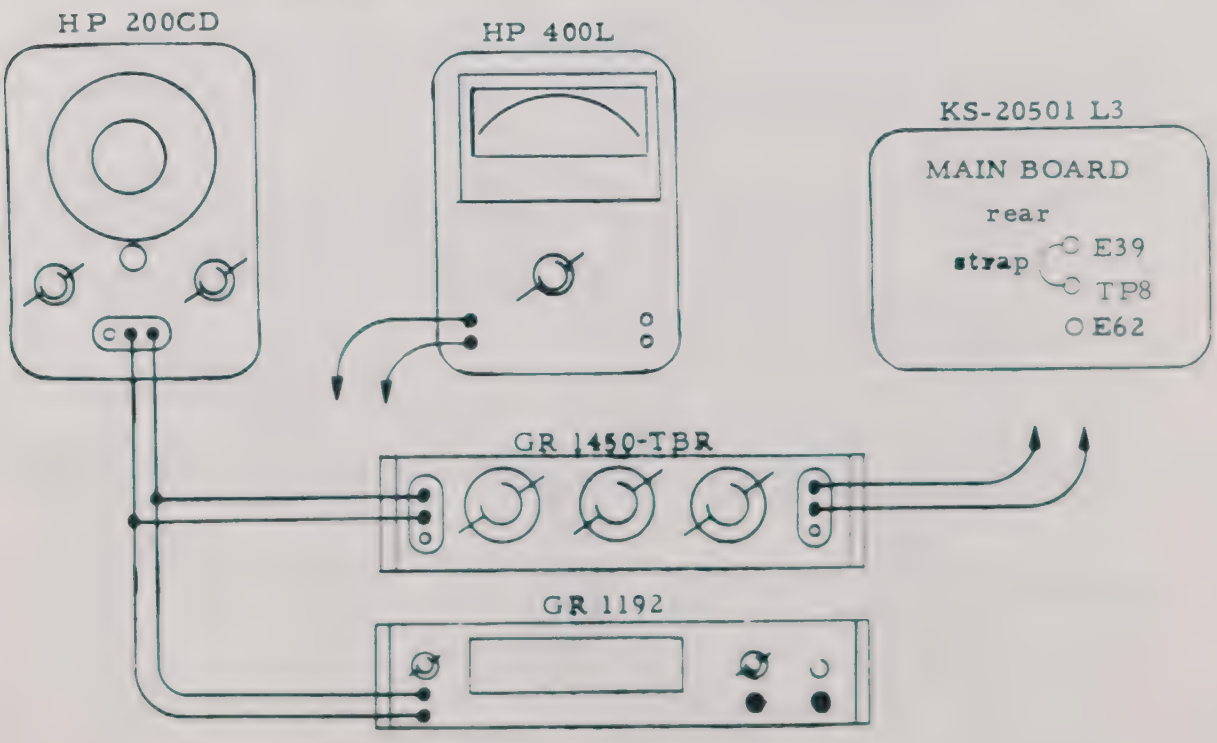


FIG. 4-D

4.5.4.a The filters are adjusted at the factory to have the frequency characteristics shown below. If the deviations observed are outside the tolerances given, the set should be returned to the manufacturer for repair.

.b Remove the strap connecting tie points E39 and E38 (TP8) on the main assembly board.

.c Adjust the oscillator output to a level of approximately -3 dBm at 360 Hz; then set the attenuator for a 30 dB loss.

.d Connect the attenuator output to tie point E39, the common to ground tie point E62 (reference 6.2.12).

.5 SRL Filter

.a Connect the VTVM between the collector of Q307 and ground tie point E62 or chassis.

.b Adjust the oscillator output level at 360 Hz to obtain an indication of -10 dBm on the VTVM.

.c Sweep the oscillator output frequency from 100 Hz to 1,000 Hz. The output level as monitored on the voltmeter should follow the SRL characteristic given below; if a deviation from specification is apparent, see par. (4.5.4.a)

Frequency-Hz	Loss-dB *	Tolerance-dB
≦120	>20	-
200	9.5	±1.1
260	3	±0.5
360	0	±0.2
500	3	±0.5
650	10	±1.2
≧1000	>20	±1.2

* Excluding any insertion loss measurements.

.6 ERL Filter

.a Connect the VTVM to the terminal of E75 using tie point E62 or chassis for ground.

.b Adjust the oscillator output level at 1 kHz to obtain an indication of -10 dBm on the VTVM.

.c Sweep the oscillator output frequency from 50 Hz to 5 kHz. The ouput level, as monitored by the VTVM, should follow the ERL characteristic given below; if a deviation from the specification is apparent, see par. (4.5.4.a)

Frequency-Hz	Loss-dB *	Tolerance-dB
≦200	>30	-
300	21.8	±2.3
560	3	±0.4
750	0	±0.1
1000	0	±0.1
1500	0	±0.1
1965	3	±0.4
2400	10.9	±1.2
3000	32.9	±3.0
4000	42.6	±5.0
≧5000	>45	-

4.5.7 SRL HI Filter

.a Connect the V T VM to the collector of Q327, using tie point E62 or chassis for ground.

.b Adjust the oscillator output level at 2.7 kHz to obtain an indication of -10.0 dBm on the VTVM.

.c Sweep the oscillator output level from 1.5 kHz to 5 kHz. The output level as monitored by the VTVM should follow the SRL HI filter characteristic shown below; if there is a deviation from this specification, see par. (4.5.4.a)

Frequency-Hz	Loss-dB *	Tolerance-dB
≦1300	>30	-
2000	11.5	±1.3
2200	3	±0.5
2700	0	±0.2
3400	3	±0.5
3700	10.9	±1.3
≧5700	>30	-

.d Replace the strap connecting tie points E39 and E38 on the main assembly board.

*Excluding any insertion loss measurements

.8 Output Impedance

An audio oscillator, such as a Hewlett-Packard 200 CD; a V T V M such as a Hewlett-Packard 400 L; and a 600Ω±1% load resistor will be required to measure the output impedance. See FIG. 4-E.

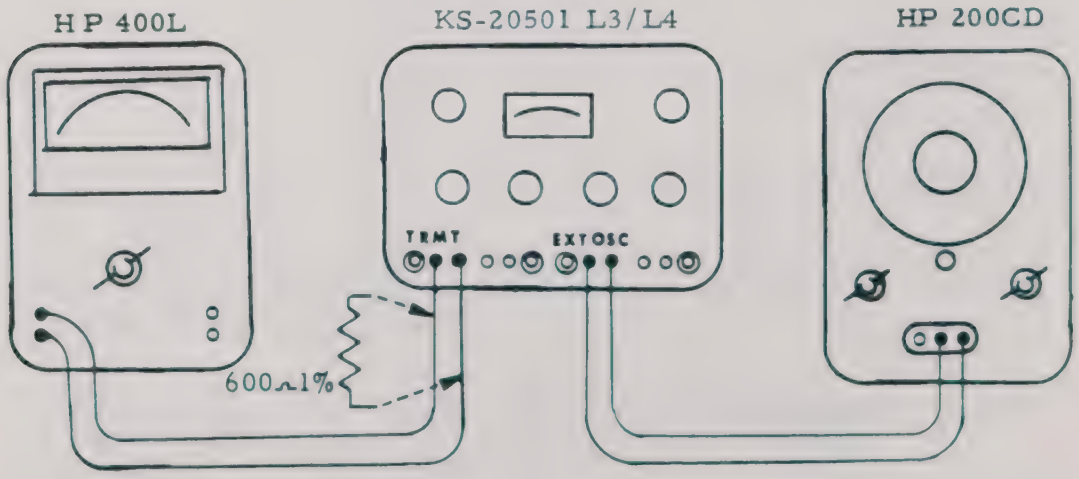


FIG. 4-E

.a Set the TEST LOCATION switch to 0 dB and the TEST TYPE switch to EXT OSC.

(Adjustment: With Pins 4 and 5 of A3 shorted together on the main assembly board, Pot R379 should be adjusted until TP4 reads 0 ±0 1 volts/dc)

4.5.8.b With the audio oscillator output connected to the EXT OSC terminals and the VTVM monitoring the output of the TRMT terminals, adjust the oscillator level to obtain a VTVM indication of 0 dBm at 1 kHz. (this is an oscillator output of approximately -6 dBm.)

.c With a 600 Ω ±1% load resistor across the TRMT terminals, a level of -6 dBm± 0.1 dB should be observed on the VT VM. The components determining the output impedance are factory selected: if the requirement is not met, the set should be returned to the manufacturer for repair.

.9 Input Impedance

An audio oscillator, such as a Hewlett-Packard 200 CD: a VTVM such as a Hewlett-Packard 400 L: and a 600Ω±1% load resistor will be required to measure the input impedance. See FIG. 4-F.

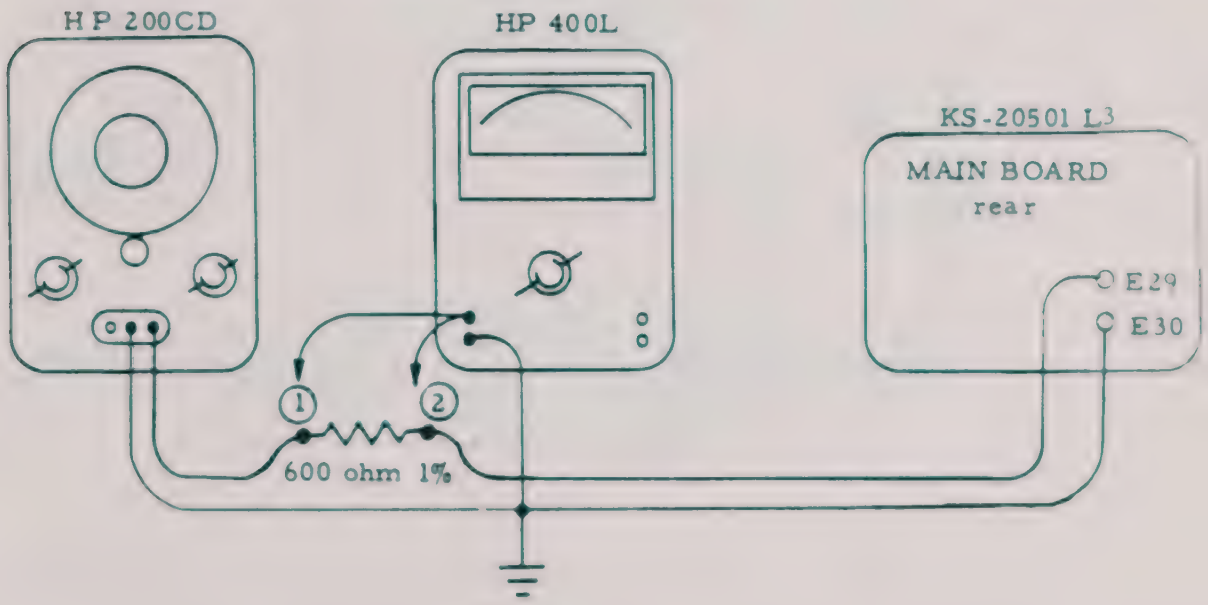


FIG. 4-F

.a Remove the shorting strap from between tie points E29 and E33 on the main board.

.b Connect the test equipment to the Test Set as shown in FIG. 4-F.
NOTE: Use caution to assure that the ground return is properly established.

.c With the 600 Ω ±1% load resistor connected in series, and the VTVM connected across the audio oscillator Position 1, adjust the oscillator to obtain a level of 0 dBm at 1 kHz. Move the VTVM connection to Position 2 and monitor the input to the Test Set and check for a loss of -6 dB ±0.1 dB. The components which determine the input impedance are factory selected. If the requirement is not met, the set should be returned to the manufacturer for repair.

(Adjustment: Monitor TP1 on the main assembly board with an oscilloscope. Adjust R151 until signal is centered on 0 ±0.1 volts dc.)

4.5.10 Meter Sensitivity

An audio oscillator, such as a Hewlett-Packard 200 CD; an attenuator, such as a General Radio 1450-TBR; and a V T V M, such as a Hewlett-Packard 400 L; will be required to measure the meter sensitivity.

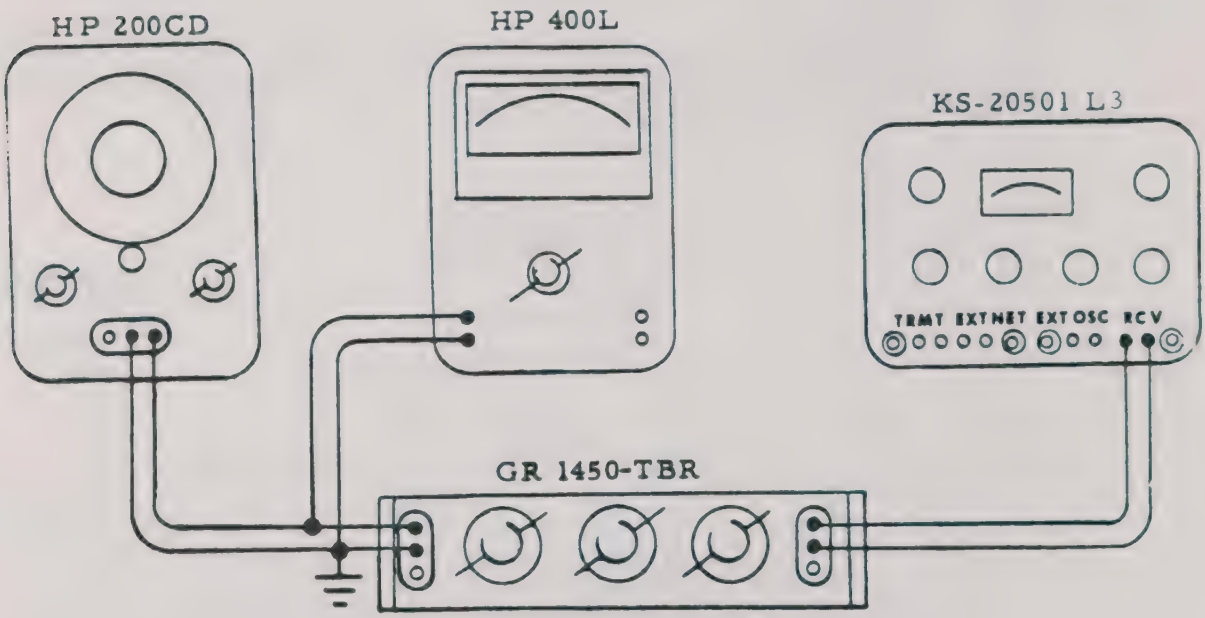


FIG. 4-G

.a With the TEST LOCATION control in the 0 dB position and the ADD dB rotary switch set to 0, connect the test equipment as shown in FIG. 4-G.

.b Set the attenuator to 00.0 and adjust the oscillator level at 1 kHz to obtain a -3 dBm reading on the VTVM.

.c Adjust the R94 METER 0 dB ADJ to obtain a 0 dB indication on the RETURN LOSS dB meter.

.d Switch the attenuator to 10.0 dB and adjust the R103 METER 10 dB ADJ potentiometer to obtain a 10.0 dB indication on the RETURN LOSS dB meter. Repeat the measurements and adjust R94 and R103 until the 0 dB and 10 dB positions are accurately reflected by the pointer.

.11 Output Level, L3

Set the controls on the Return Loss Measuring Set to the following positions: TEST LOCATION to 600; TEST TYPE to ERL; NETWORK to INT; ADD dB to 0. Adjust potentiometer R74 to obtain a 0.0 dB indication on the RETURN LOSS dB meter.

4.5.12 Output Level, L4

Set the controls on the Return Loss Measuring Set to the following positions: Test Location to 0 dB, TEST TYPE to ERL; and ADD dB to 3. Complete the loop connection between TRMT and RCV using the appropriate cable. Adjust potentiometer R74 to obtain a 0.0 dB indication on the RETURN LOSS dB meter.

5.0 TROUBLESHOOTING TECHNIQUES

5.1 General

This section is designed to aid in the isolation of possible malfunctions of the equipment. The outlined procedures should be used after it has been established that the instrument is not operating to the standards delineated in Performance Checks, Section 4.4, or cannot be calibrated to the standards in Calibration Procedures, Section 4.5. Familiarity with the overall operation of the instrument, Section 3.0, and the detailed operation of the individual units, Section 2.2, is a prerequisite. Any malfunction should be related to the most probable area and traced back to its source; typical voltages and waveforms, shown in Section 6.0, represent key points in the instrument and should be used as aids to localization. Troubleshooting from Front Panel Symptoms, Section 5.2, contains a summary of RETURN LOSS dB meter indications which may be classified as pointing to instrument malfunction, as well as procedures that may be helpful in isolation of the probable cause; Isolating Malfunctions, Section 5.3, contains a progressive diagnostic table based on specific section malfunctions as they relate to the typical voltages and waveforms shown with the schematics.

The voltages and waveforms shown with the schematics are based on the following control positions and/or signal inputs, with ac and dc measurements taken between test point and ground terminal E202.

PWR	ON
THL OR ADD	0.0
TEST LOCATION	+0 dB
TEST TYPE	ERL
ADD dB	0
NETWORK	INT

For the Receive Section of the instrument, apply a 1 kHz single tone signal to the RCV terminals at -3 dB level for measuring voltages or observing waveforms at test points TP1, TP2, and TP3.

For the Transmit Section of the instrument, remove the 1 kHz signal from the RCV terminals and connect a 600 Ω ± 1% resistor across the TRMT terminals for measuring voltages or observing waveforms at all remaining test points. Exceptions to be noted are the waveforms taken at TP4 with the TEST TYPE switch in the SRL and SRL HI positions respectively.

When servicing, remember that semiconductors are more prone to failure than any other components. Check the operation of transistors by establishing that they pass a signal and that the base emitter voltages are within about a volt of each other at all times when powered. Check that the resistance of diodes is high in one direction and low in the other; check that capacitors are

not shorted, and that they will pass an ac signal. Replace any component suspected of being defective to verify localization of a specific fault. A visual check for possible burned or loose components, loose connections, or any other obvious condition that would cause malfunction, should be performed.

The use of a pencil-type soldering iron with less than a 40 watt maximum capacity is recommended to prevent possible damage to the printed circuit board or components. If the iron is ac powered, use an isolating transformer between the iron and the source. Do not use a soldering gun as damaging voltages can be induced in components.

5.2 Troubleshooting from Front Panel Symptoms

.1	PWR to ON NETWORK to INT	ADD dB to 0 TEST LOCATION to 600
	Meter does not read 0 dB on:	
	a. TEST TYPE position ERL	Check ERL filter per Par. 4.5.6
	b. TEST TYPE position SRL	Check SRL filter per Par. 4.5.5
	c. TEST TYPE position SRL HI	Check SRL HI filter per Par. 4.5.7
	d. None of the above	(1) Check the power source. (2) Check fuse F1. (3) Check Transmit Section per Section 5.1. (4) Check Receive Section per Section 5.1.
.2	PWR to ON NETWORK to INT ADD dB to 0	THL to 0.0 TEST LOCATION to +0 dB TEST TYPE to ERL
	Meter does not read 0 or 10 when switching the ADD dB control from 0 to -10	Check meter sensitivity calibration per Par. 4.5.10
.3	PWR to ON ADD dB to -10 THL to 0.0	TEST LOCATION to +0 dB TEST TYPE to ERL RCV strapped to TRMT
	a. Meter does not read 10 dB	(1) Check S5 (2) Check R8 through R16 (3) Check A1 and A2
	b. Meter does not track proportionately when adjusting THL from 0 through 10	(1) Check S6 (2) Check R47 through R51
	c. Meter does not tract proportionately when adjusting THL from .0 through .8	(1) Check S7 (2) Check R52 through R61

5.3 Isolating Malfunctions

.1 Power Supplies

+12 V supply does not read +12 ±0.70 V when checked per Par. 4.5.2.

L1: Using the information supplied on Schematic 6.2.8, check voltages and waveforms to isolate the malfunction.
L2: Using the information supplied on Schematic 6.2.11, check voltages and waveforms to isolate the malfunction.

-12 V supply does not read -12 ±0.70 V when checked per Par. 4.5.3.

L1: Using the information supplied on Schematic 6.2.8, check voltages and waveforms to isolate the malfunction.
L2: Using the information supplied on Schematic 6.2.11, check voltages and waveforms to isolate the malfunction.

.2 Transmit Section

Transmit Section does not function.

L1: Use the information supplied on Schematic 6.2.12.
L2: Use the information supplied on Schematic 6.2.13.

L1 and L2: Check the voltages and waveforms using the following sequence of test points, to isolate malfunction to a specific area: TP9, 8, 13, 4, 5, 6, 7.

NOTE: If it becomes desirable to disable the feedback, remove the jumper connected the anode of CR4 and pin 2 of A6; next connect a -3.5 V dc voltage to pin 2 of A6, from a source impedance of less than 500 Ω to allow a fixed gain operation.

.3 Receive Section

Receive Section does not function.

L1: Use the information supplied on Schematic 6.2.12.
L2: Use the information supplied on Schematic 6.2.13.

L1 and L2: Check the voltage and waveforms using the standard single tone signal, reference Par. 5.1, and in the following sequence to aid in isolating a malfunction to a particular section: TP1, 2, 3, 10, 12.

NOTE: Reference Par. 4.4.4.d. Using the test set-up outlined in this paragraph, the following should be noted:

a. Steps 1-5 check the ADD dB switch.
b. Steps 6-14 check the THL 1 dB attenuator steps.
c. Steps 15-18 check the THL .2 dB attenuator steps.
d. Step 19 checks the 0 dB wiring, the S2 pad, and amplifier A2.
e. Step 20 checks the +13 dB wiring switch S2 and the pad pad on S2.

6.0 DRAWINGS

6.1 General

This section contains the schematic diagrams with typical voltages and waveforms, supplemented by component and path locating diagrams, necessary to assist the field engineer or technician in the maintenance, calibration, and use of this equipment.

Notes
Unless otherwise specified: resistors are in ohms, 1/2 watt, 5%.
capacitors are in microfarads.

Components within broken lines (- - -) are mounted on printed circuit boards.

Nomenclature in blocks [ ] indicate front panel markings.

An asterisk * indicates that these values may be trimmed during test.

6.2 List of Drawings

6.2.1 Main Board, Component Side, L3A D481-201/W sheet 1

6.2.2 Main Board, Circuit Side, L3A D481-201/W sheet 2

6.2.3 Main Board, Component Side, L4A D481-204/W sheet 1

6.2.4 Main Board, Circuit Side, L4A D481-204/W sheet 2

6.2.5 Main Schematic, Filter Section, L3A and L4A D481-002-1/Z sheet 1

6.2.6 AC Power Supply, Component Side, L3A C481-202/D sheet 1 and FM481-403/D

6.2.7 AC Power Supply, Circuit Side, L3A C481-202/D sheet 2 and FM481-403/D

6.2.8 AC Power Supply Schematic, L3A D481-002-1/Z sheet 1

6.2.9 DC Power Supply, Component Side, L4A C481-203/C sheet 1 and FM481-401/A

6.2.10 DC Power Supply, Circuit Side, L4A C481-203/C sheet 2 and FM481-401/A

6.2.11 DC Power Supply Schematic, L4A D481-002-2/Z sheet 1

6.2.12 Main Schematic, L3A D481-002-1/Z sheets 1 and 2

6.2.13 Main Schematic, L4A D481-002-2/Z sheets 1 and 2

6.2.14 Switch Detail Test Location L3A and L4A C481-208/C

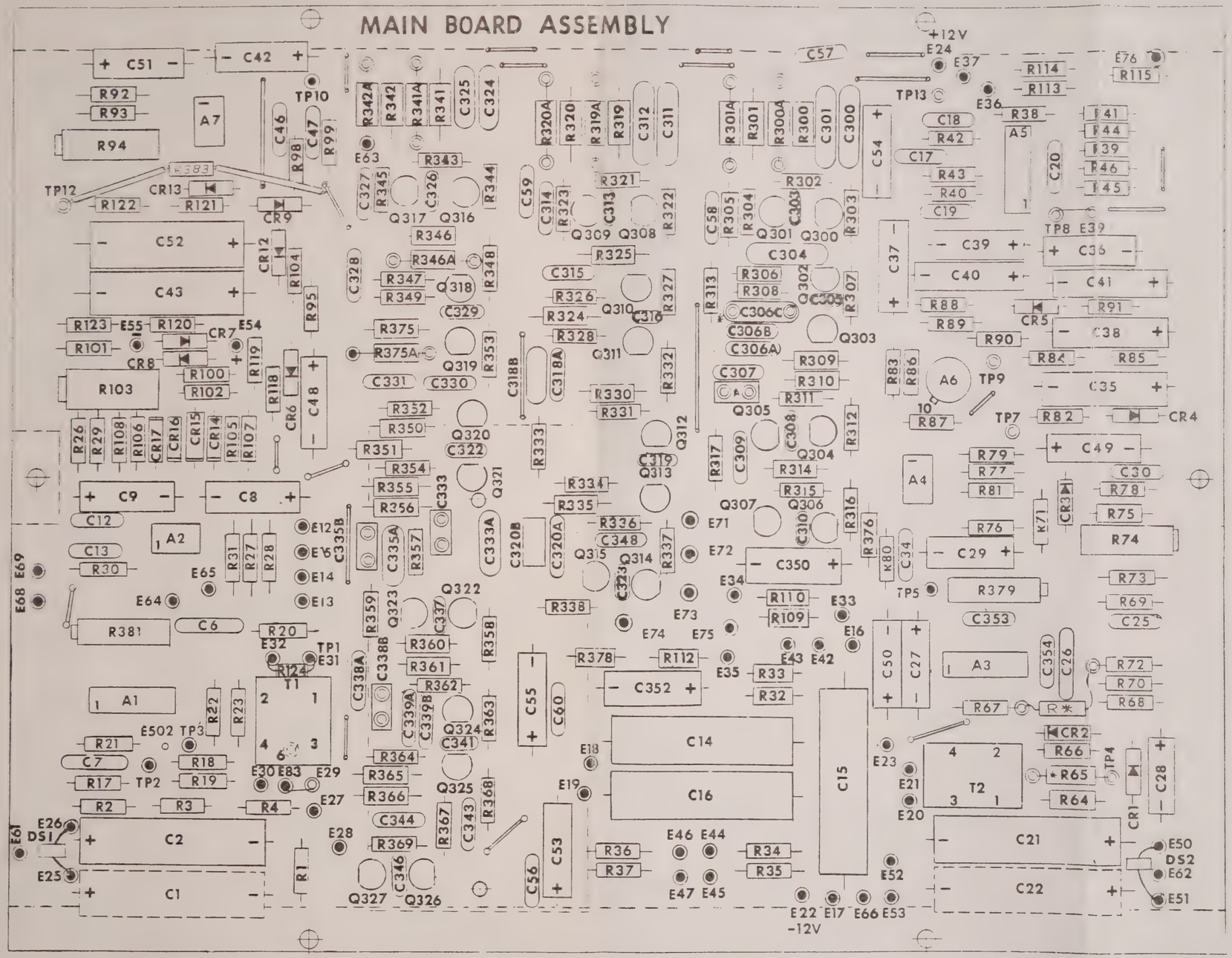
6.2.15 Switch Detail Add dB L3A and L4A C481-207/C

6.2.16 Switch Detail TRL OR ATT Attenuator L3A and L4A C481-206/A and FM481-405/A

6.2.17 ERL Filter Board, Component Side B481-221/B sheet 1

6.2.18 ERL Filter Board, Circuit Side B481-221/B sheet 2

MAIN BOARD ASSEMBLY


+12V
-12V
C51
C42
C52
C43
C9
C8
C12
C2
C1
C48
C6
C14
C16
C15
C21
C22
C54
C57
C58
C59
C60
C55
C56
C53
C50
C27
C37
C39
C40
C36
C41
C38
C35
C49
C30
C29
C350
C352
C353
C354
C26
C28
C20
A1
A2
A3
A4
A5
A6
A7
T1
T2
Q317
Q316
Q309
Q308
Q301
Q300
Q318
Q310
Q303
Q319
Q311
Q305
Q320
Q312
Q304
Q321
Q313
Q307
Q306
Q322
Q315
Q314
Q323
Q324
Q325
Q327
Q326
TP1
TP2
TP3
TP4
TP5
TP7
TP8
TP9
TP10
TP12
TP13
CR1
CR2
CR3
CR4
CR5
CR6
CR7
CR8
CR9
CR12
CR13
DS1
DS2
R92
R93
R94
R383
R122
R121
R123
R120
R101
R103
R100
R102
R119
R118
R104
R95
R99
R98
R26
R29
R108
R106
R107
R105
R381
R20
R124
R22
R23
R21
R18
R19
R17
R2
R3
R4
R1
R31
R27
R28
R30
R342A
R342
R341A
R341
R343
R345
R344
R346
R346A
R347
R349
R348
R375
R375A
R353
R352
R350
R351
R354
R355
R356
R359
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R361
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R363
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R366
R368
R369
R367
R358
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R325
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R328
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R331
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R337
R338
R378
R112
R110
R109
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R302
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R305
R303
R306
R308
R307
R313
R309
R310
R311
R312
R317
R314
R315
R316
R376
R114
R113
R38
R42
R43
R40
R19
R88
R89
R90
R84
R85
R91
R82
R79
R77
R81
R76
R80
R379
R73
R69
R74
R75
R78
R72
R70
R68
R67
R66
R65
R64
R41
R44
R39
R46
R45
C325
C324
C327
C326
C328
C329
C331
C330
C322
C333
C335A
C335B
C333A
C320B
C320A
C348
C314
C313
C311
C312
C315
C316
C318B
C318A
C307
C306C
C306B
C306A
C308
C309
C310
C303
C305
C304
C302
C339A
C339B
C338A
C338B
C337
C341
C343
C344
C346
C333B
C323
C334
C336
C18
C17
C19
C83
C82
C84
C86
C87
C88
C89
C90
C91
C92
C93
C94
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C102
C103
C104
C105
C106
C107
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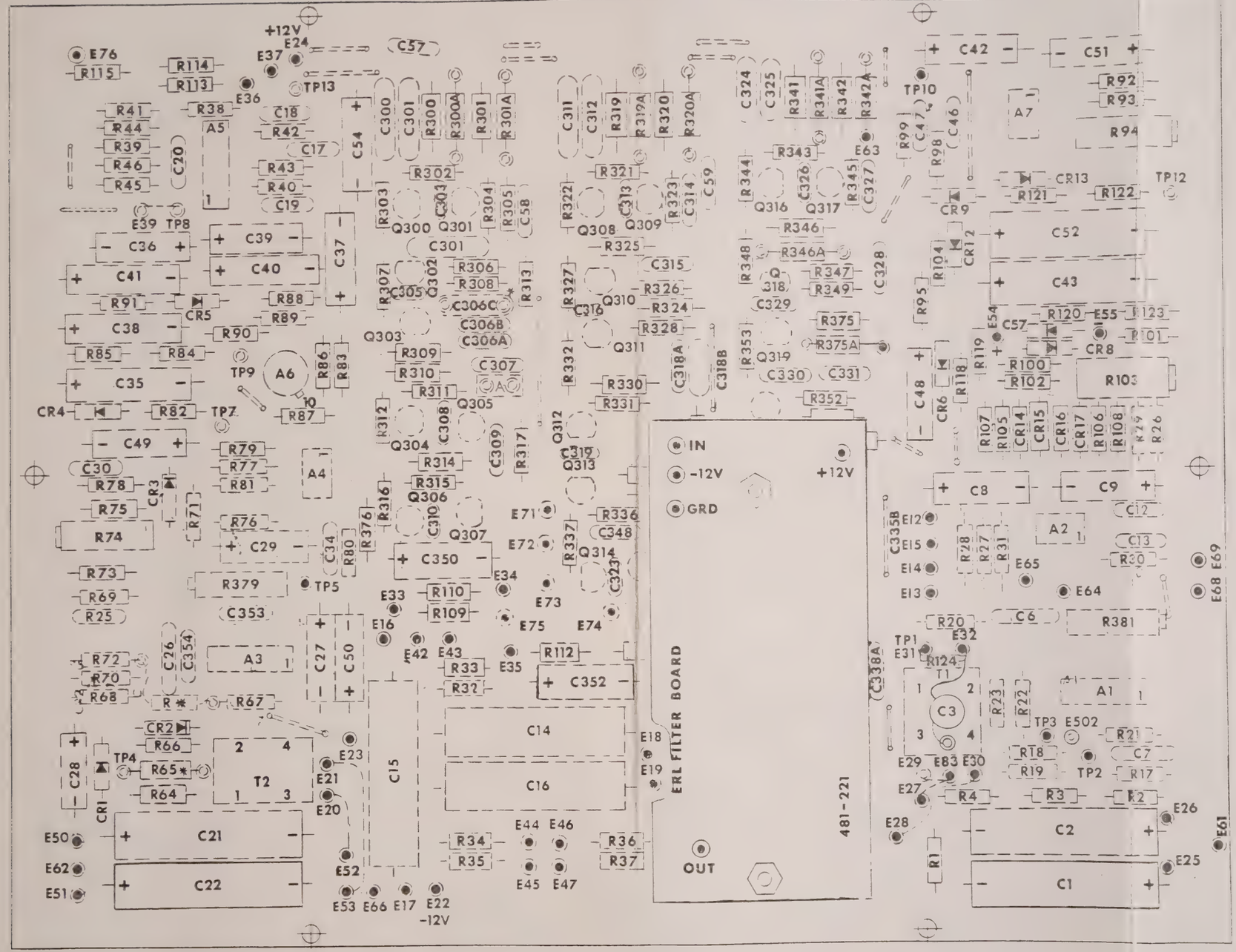
C124
C125



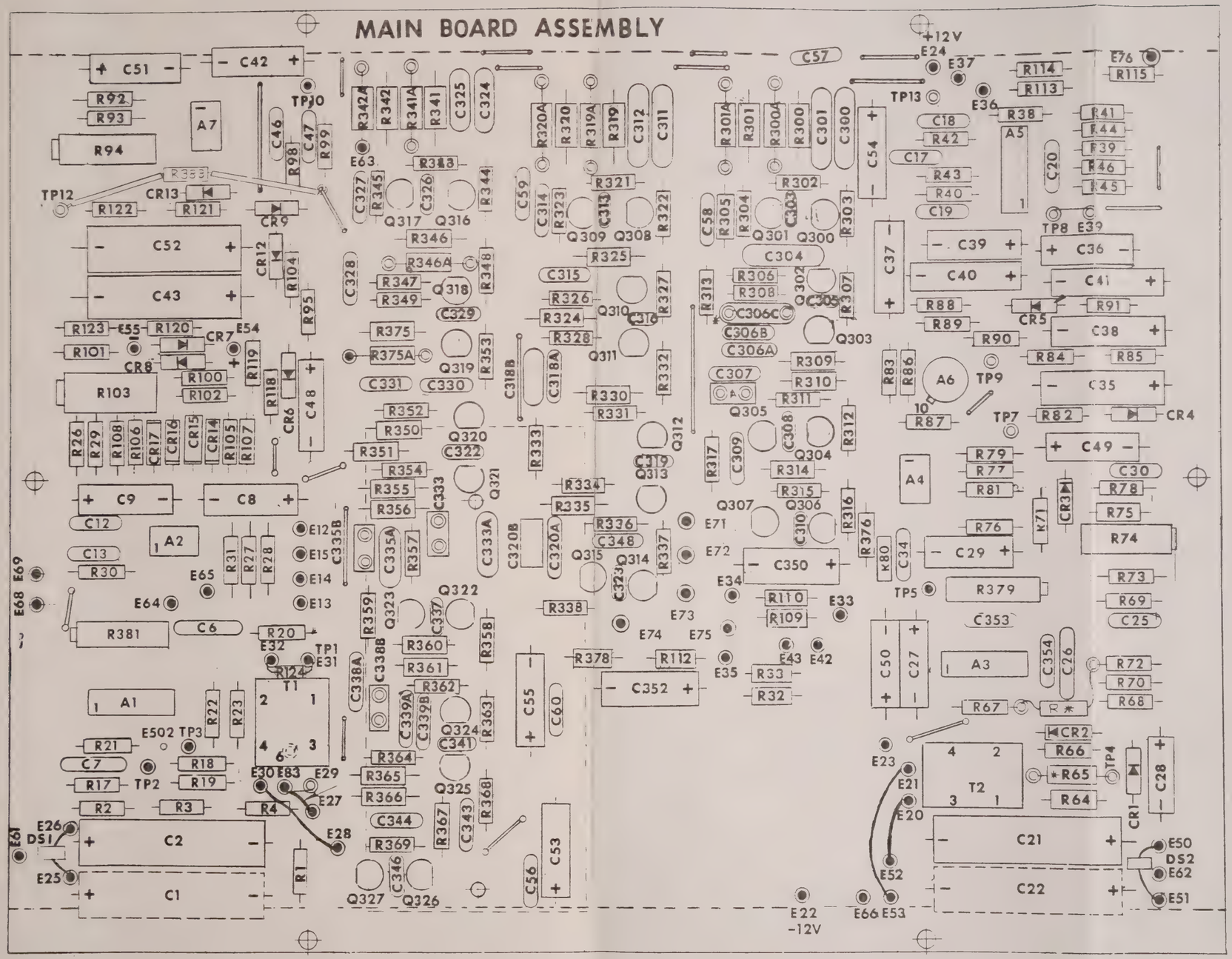
CIRCUIT SIDE

RETURN LOSS
MEASURING SET
KS-20501 L3A

MAIN BOARD
Circuit Side

D481-201 sheet 2
6.2.2

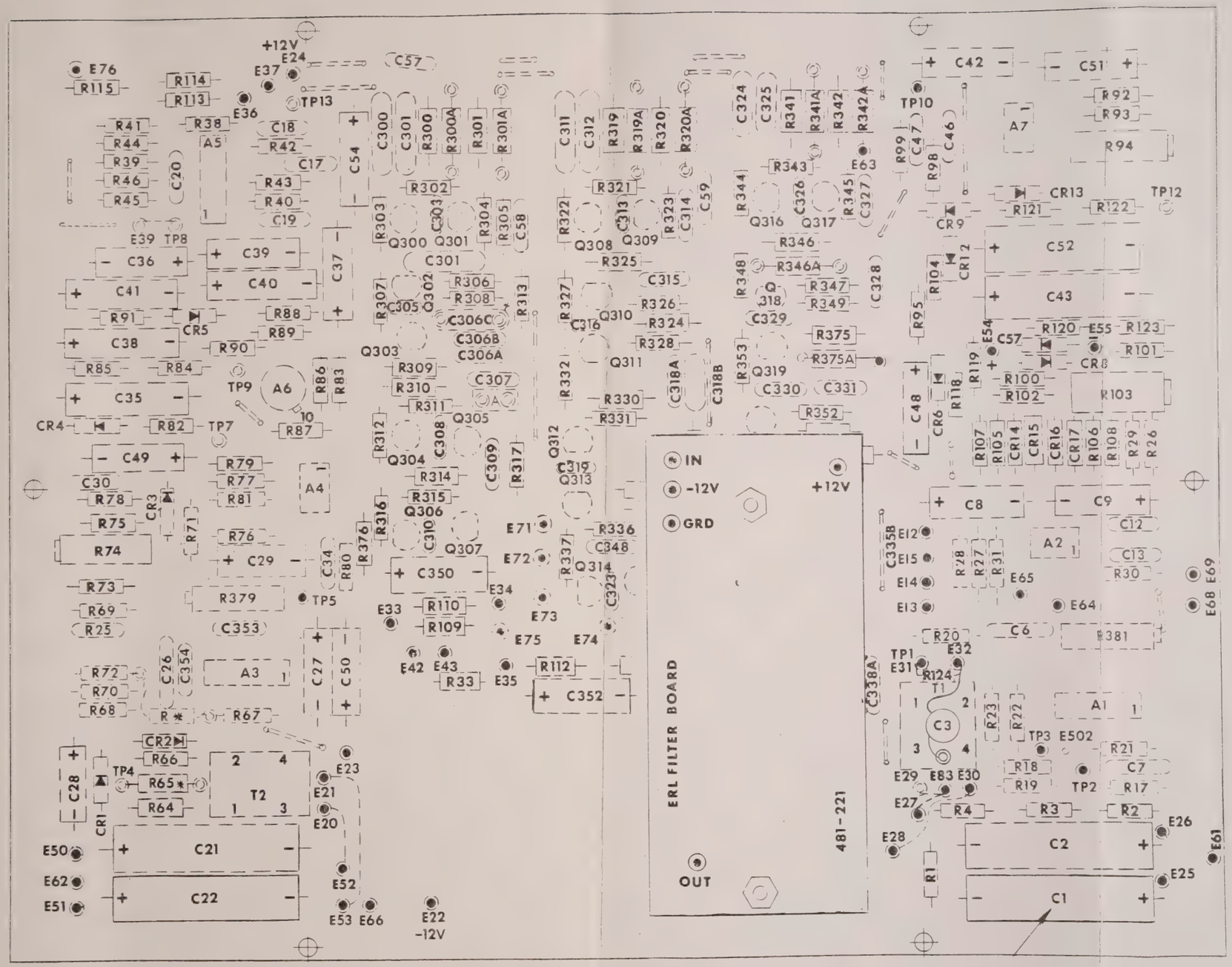
MAIN BOARD ASSEMBLY



RETURN LOSS
MEASURING SET
KS-20501 L4A

MAIN BOARD
Component Side

D481-204 sheet 1
6.2.3

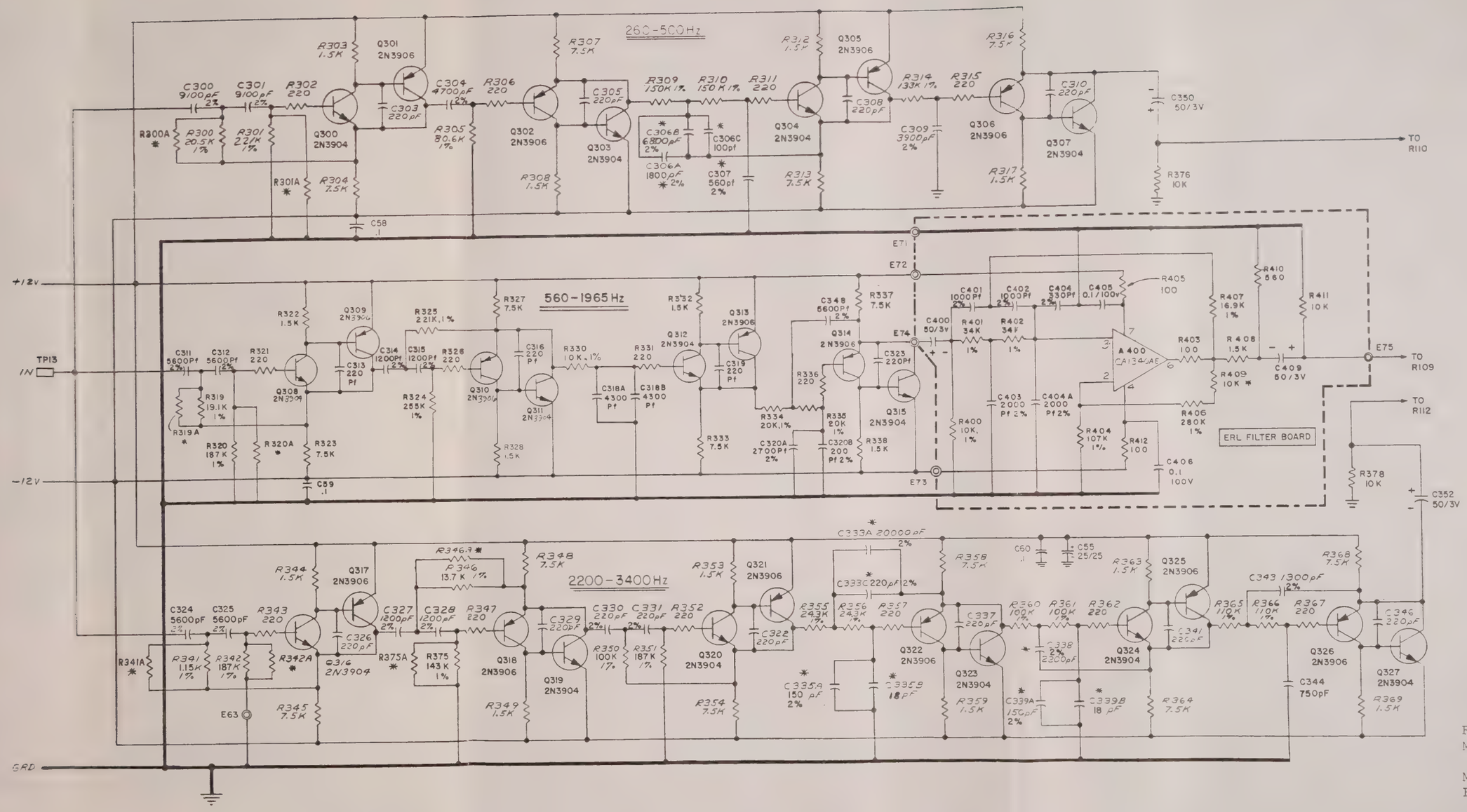


CIRCUIT SIDE

RETURN LOSS
MEASURING SET
KS-20501 L4A

MAIN BOARD
Circuit Side

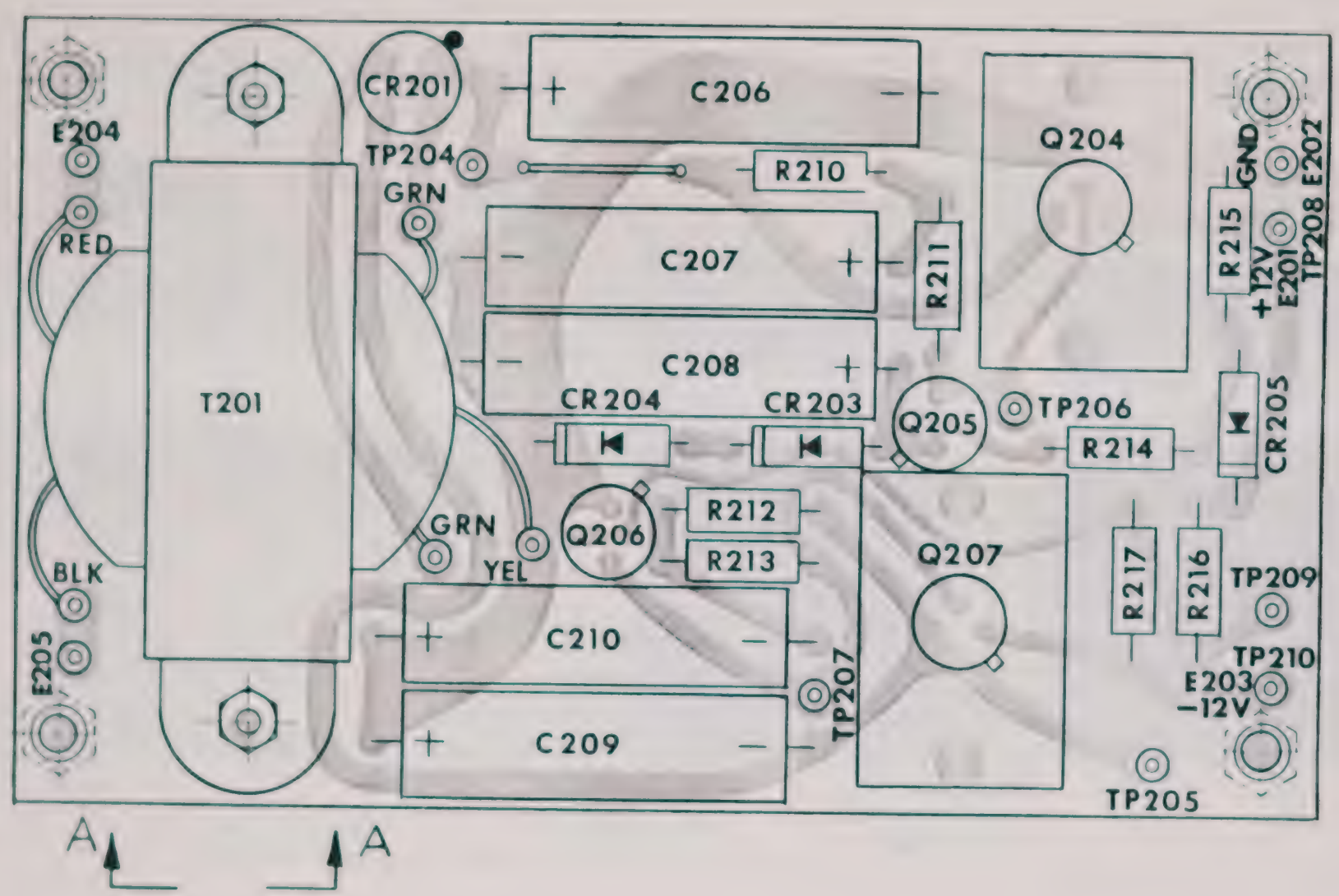
D481-204 sheet
6.2.4

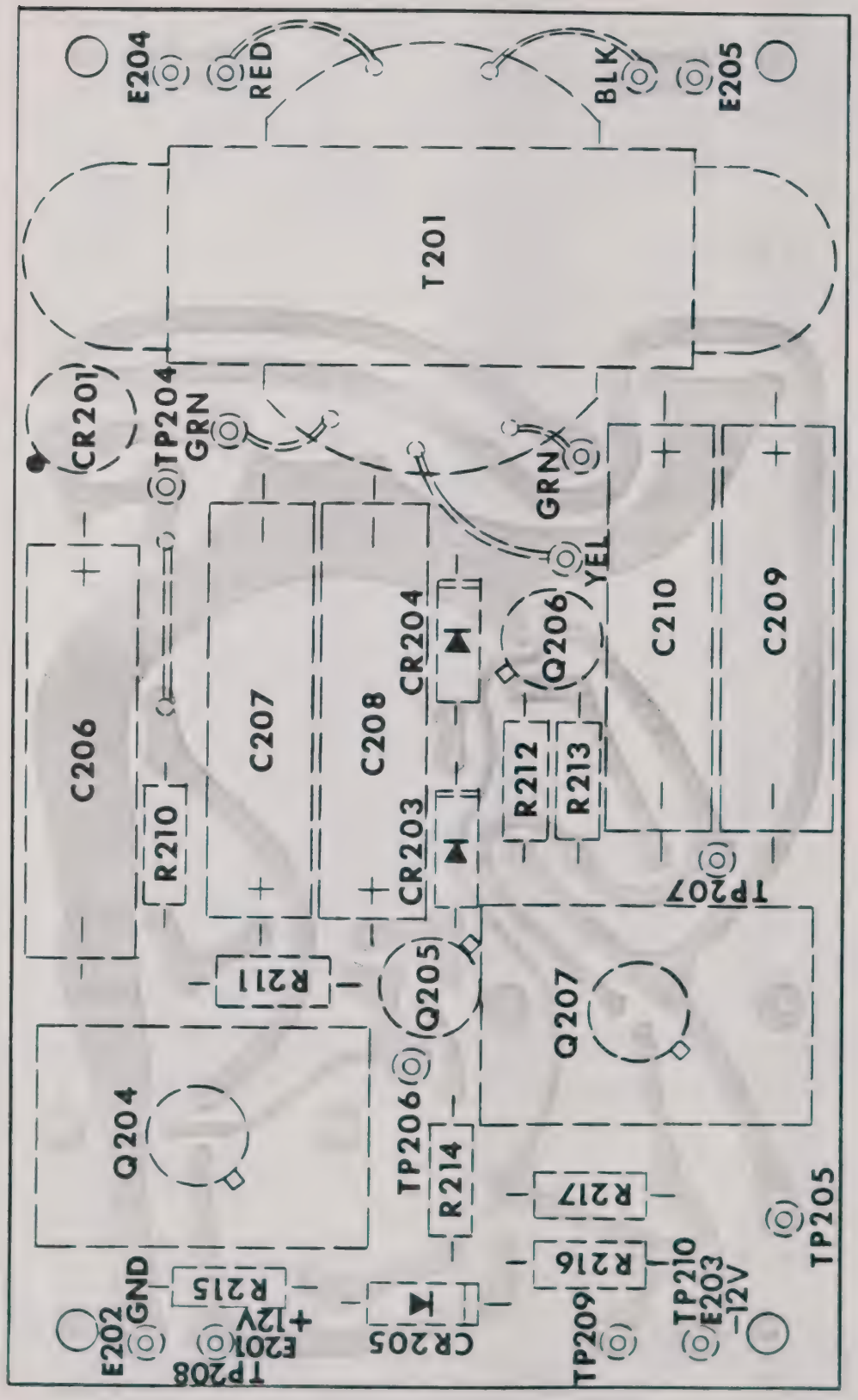


RETURN LOSS
MEASURING SET

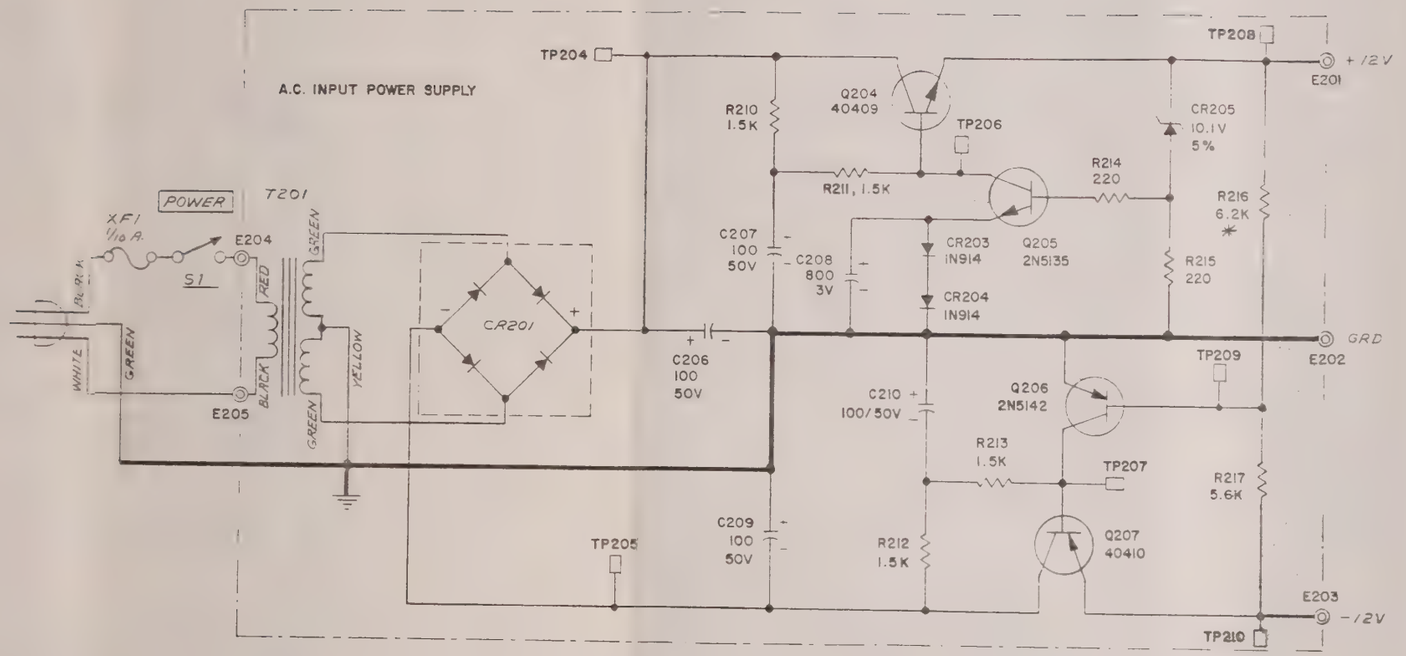
MAIN SCHEMATIC
Filter Section

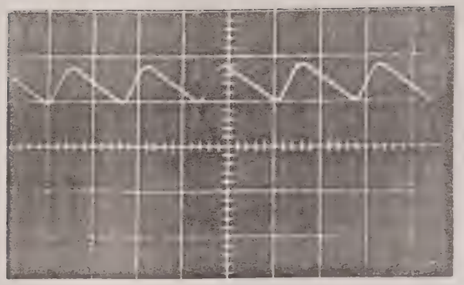
D481-002-1
6.2.5


E204
CR201
C206
TP204
GRN
R210
Q204
GND
RED
C207
R211
R215
+12V
E201
TP208
E202
T201
C208
CR204
CR203
Q205
TP206
R214
CR205
GRN
Q206
R212
YEL
R213
Q207
R217
R216
TP209
BLK
C210
TP210
E205
TP207
E203
-12V
C209
TP205
A
A

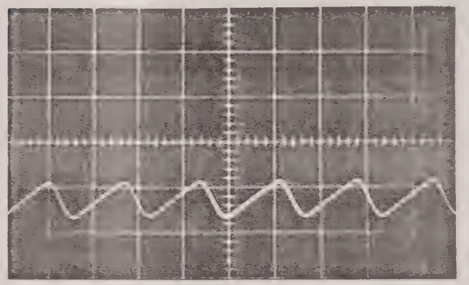


C481-202 sheet 2
and PM481-402
6.2.7





TP204 Vert= 5V/cm, Hor= 5ms/cm



TP205 Vert= 5V/cm, Hor= 5ms/cm

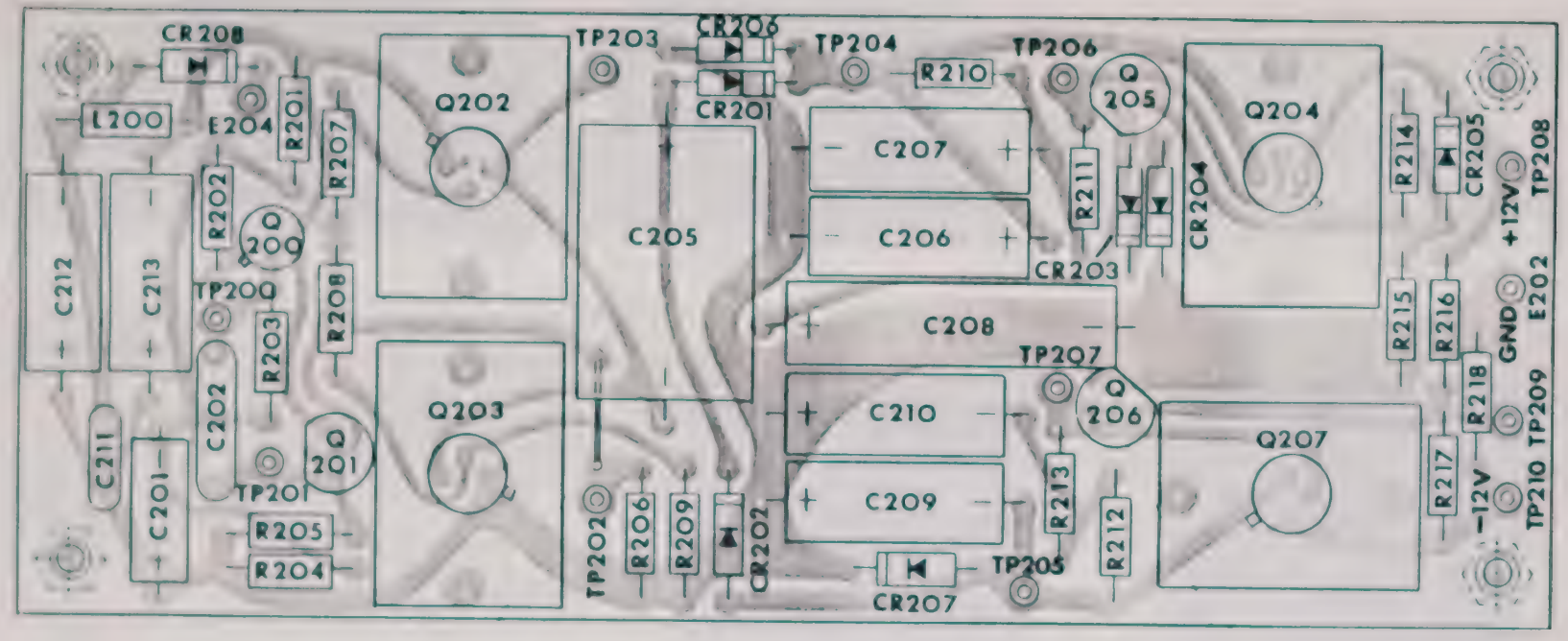
Typical Voltages

TP	VDC	VAC
204	+25.70	-
205	-25.30	-
206	+12.90	-
207	-12.70	-
208	+12.20	0.0008
209	+ 0.60	-
210	-12.00	0.0006

RETURN LOSS
MEASURING SET
KS-20501 L3

AC POWER SUPPLY
Schematic

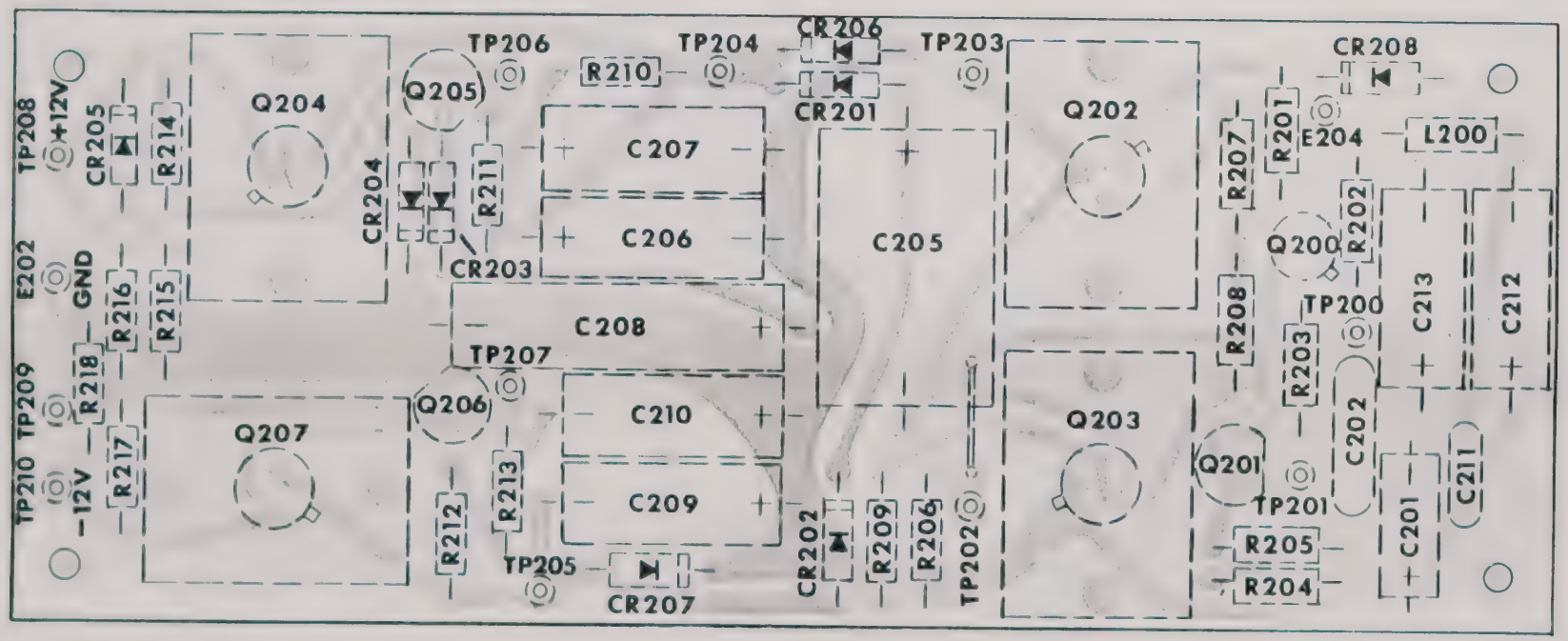
D481-002-1 sheet 1
6.2.8



RETURN LOSS MEASURING SET

DC POWER SUPPLY
Component Side

C481-203 sheet 2
and PM481-403
6.2.10

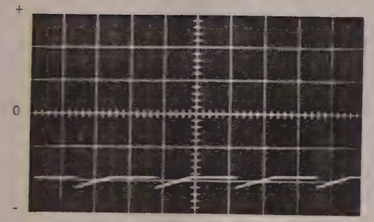


RETURN LOSS MEASURING SET

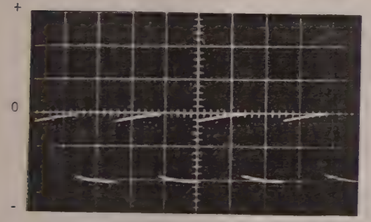
DC POWER SUPPLY
Component Side

List of Materials - See 7-6 and 7-7

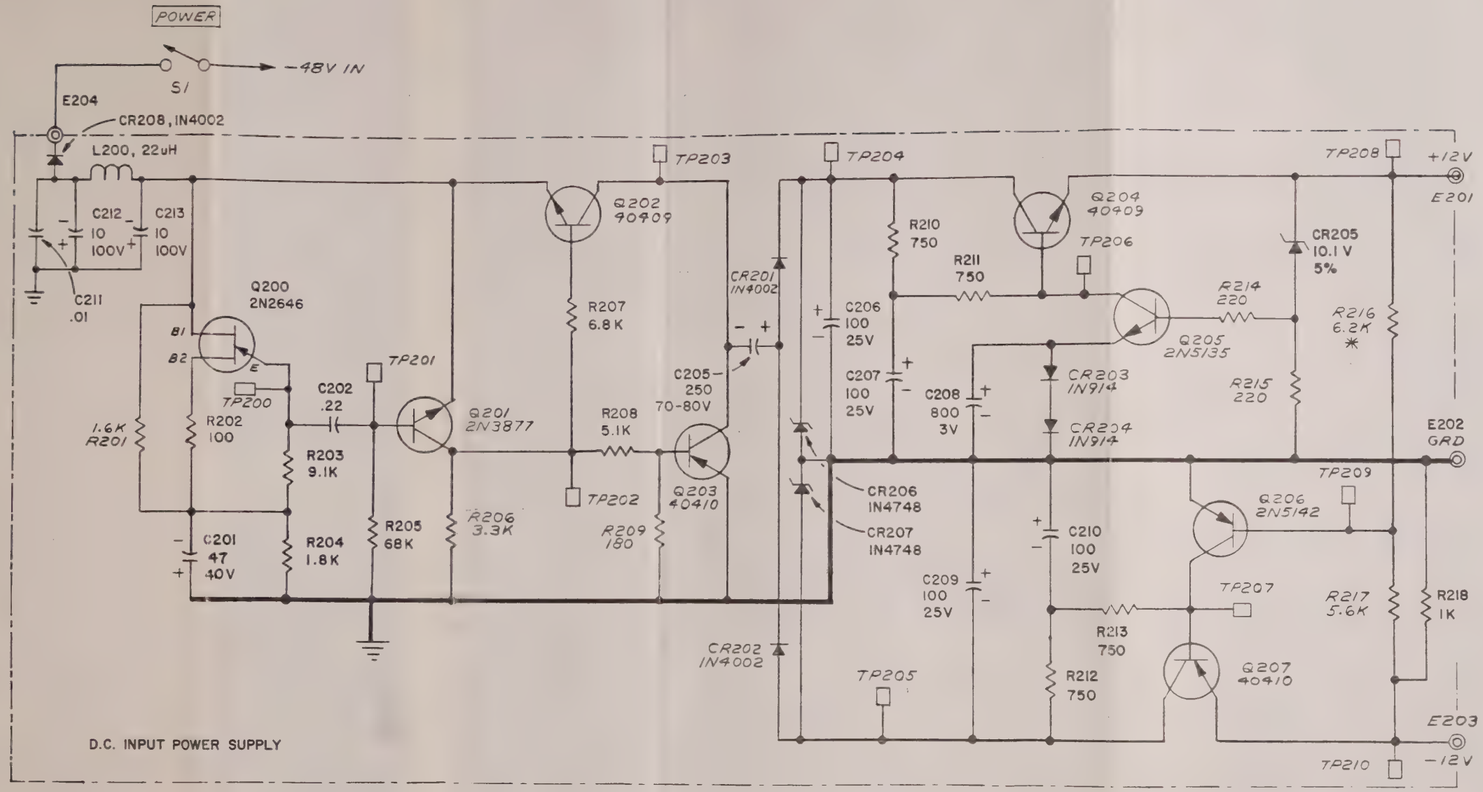
Assembly Drawings - See 6.2.9 and 6.2.10

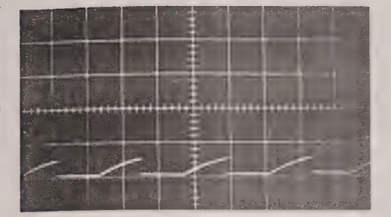


TP201 Vert= 20V/cm, Hor= 2ms/cm

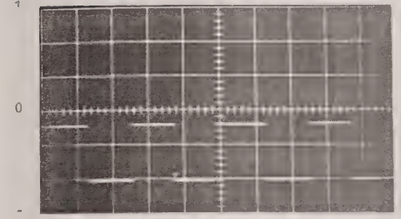


TP203 Vert= 20V/cm, Hor= 2ms/ cm





TP200 Vert= 20V/cm, Hor= 2ms/cm



TP202 Vert= 20V/cm, Hor= 2ms/cm

Typical Voltages

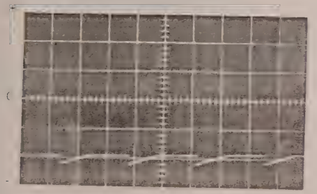
TP	VDC	VAC
204	+25.70	-
205	-25.30	-
206	+12.90	-
207	-12.70	-
208	+12.20	0.0008
209	+ 0.60	-
210	-12.00	0.0006

RETURN LOSS
MEASURING SET
KS-20501 L4

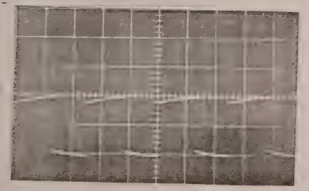
DC POWER SUPPLY
Schematic

List of Materials - See 7-6 and 7-7

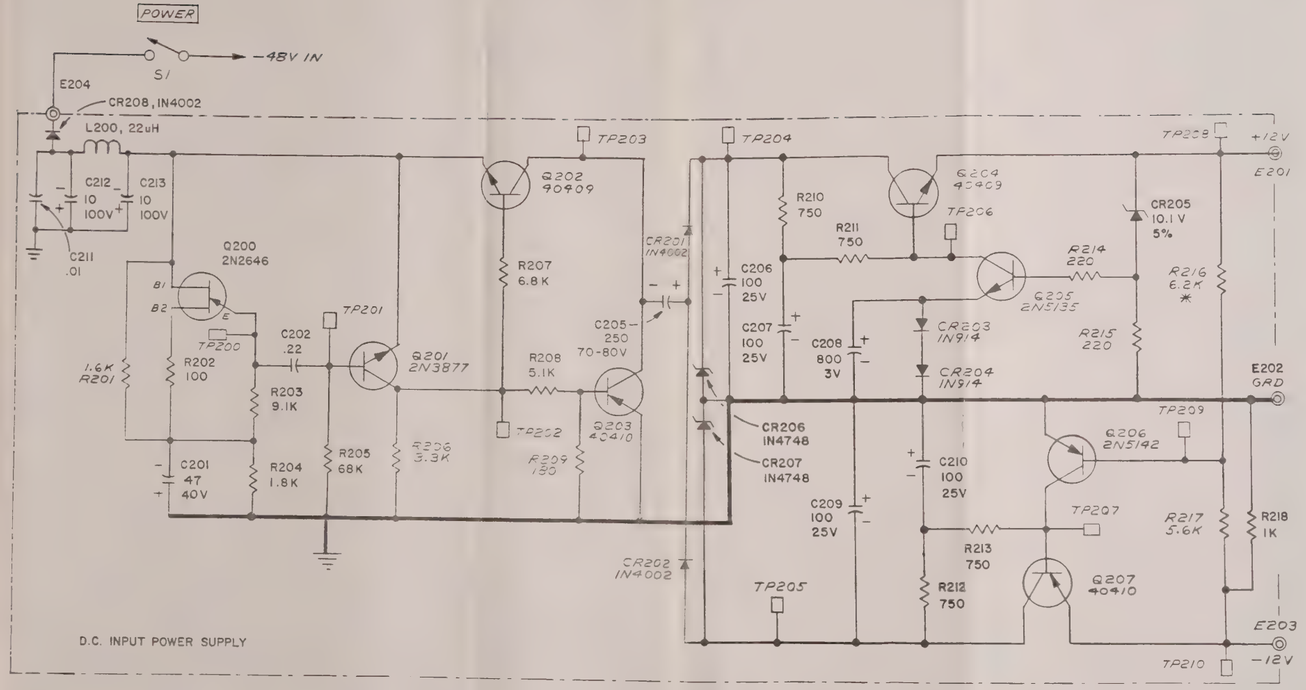
Assembly Drawings - See 6.2.9 and 6.2.10

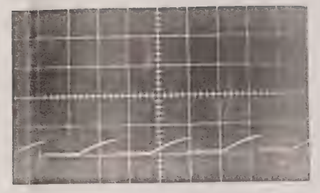


TP201 Vert= 20V/cm, Hor= 2ms/cm

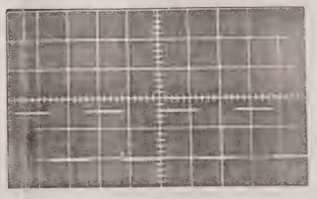


TP203 Vert= 20V/cm, Hor= 2ms/ cm





TP200 Vert= 20V/cm, Hor= 2ms/cm



TP202 Vert= 20V/cm, Hor= 2ms/cm

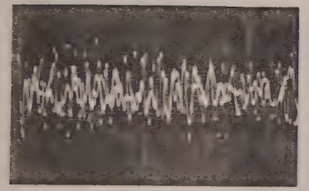
Typical Voltages

TP	VDC	VAC
204	+25.70	-
205	-25.30	-
206	+12.90	-
207	-12.70	-
208	+12.20	0.0008
209	+ 0.60	-
210	-12.00	0.000o

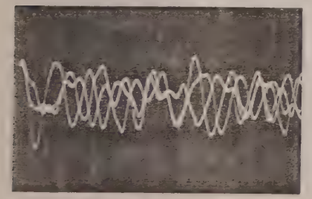
RETURN LOSS
MEASURING SET
KS-20501 L4

DC POWER SUPPLY
Schematic

D481-002-2 sheet
6.2.11

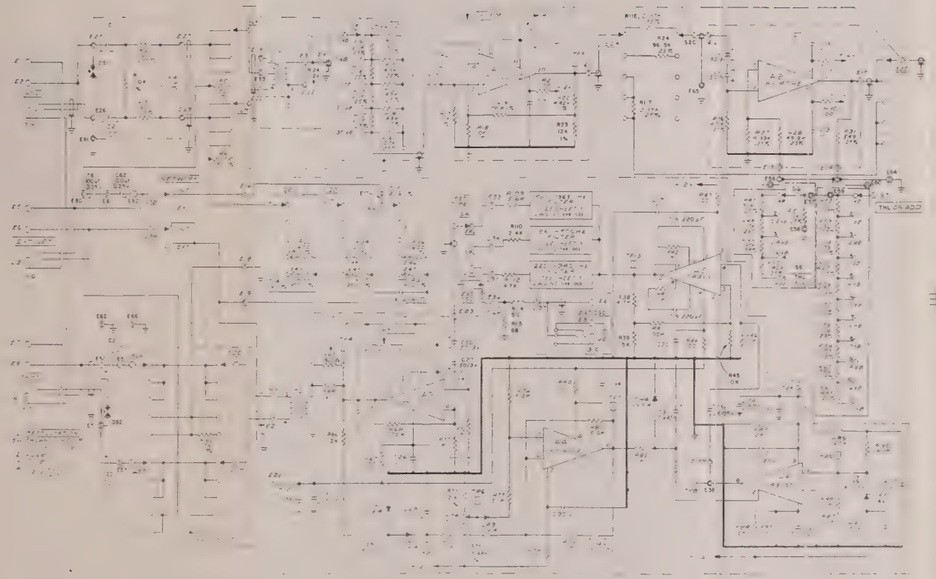


ERL TP4 Vert=2V/cm, Hor=2ms/cm



SRL TP4 Vert=2V/cm, Hor=2ms/cm

SRL HI TP4 Vert=2V/cm, Hor=2ms/cm



...ge 1 kHz, -3 dB level, ... kHz.
PWR. ON: THL. 0 dB. TEST LOCATION:
+0 dB: TEST TYPE, EXT OSC.
ADD dB. 0.

TP12 Vert=1 V/cm, Hor=... ms/cm

Typical Voltages

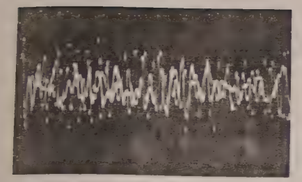
TP	VDC	VAC
1	ac only	0.1
2	0.0	0.003
3	±1.0	1.3
4	-0.10	1.3
5	+3.50	-
6	+3.40	-
7	-3.90	
8	+4.0	0.035
9	-0.08	0.055
10	-0.14	0.85
13	-0.03	0.64

List of Materials - See 7-2, 7-3, 7-4, 7-5

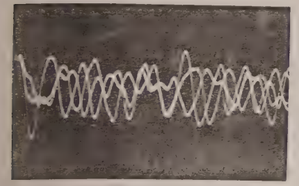
Assembly Drawings - See 6.2.1 and 6.2.2

RETURN LOSS
MEASURING SET
KS-20501 L3 A

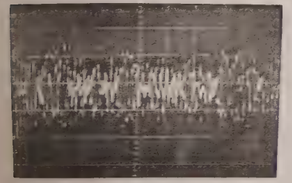
MAIN SCHEMATIC



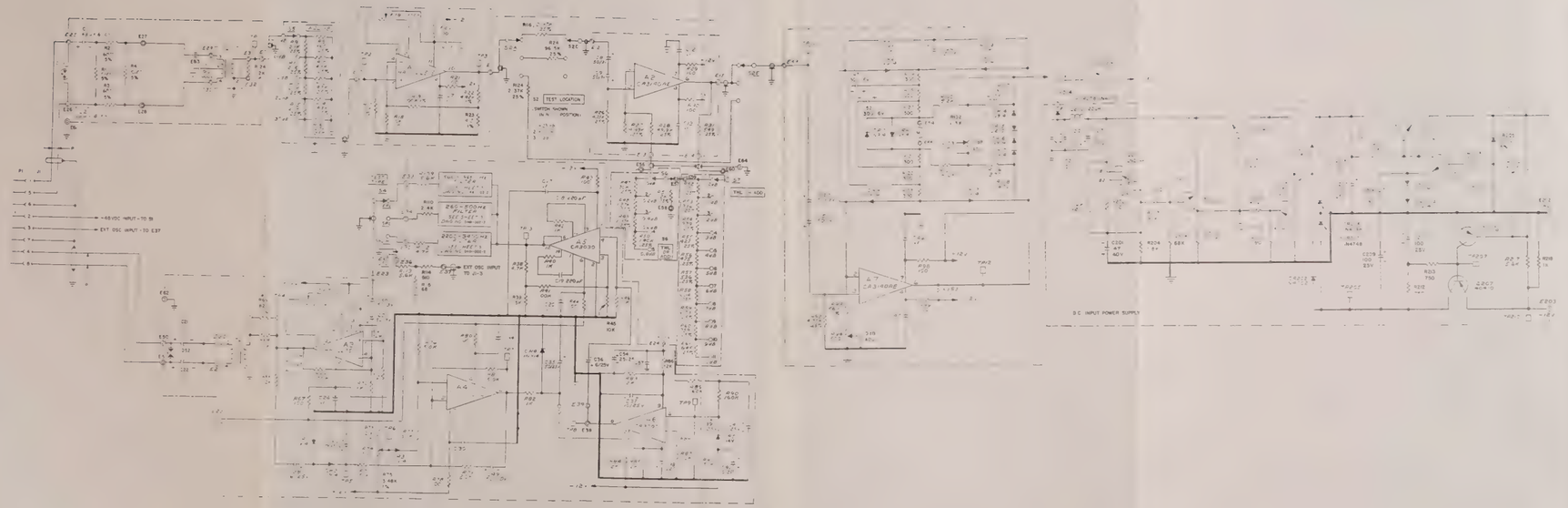
ERL TP4 Vert=2V/cm, Hor=2ms/cm



SRL TP4 Vert=2V/cm, Hor=2ms/cm



SRL HI TP4 Vert=2V/cm, Hor=2ms/cm



TEST TYPE EXT CRT.

TP12 Vert=1 V

Typical Voltages

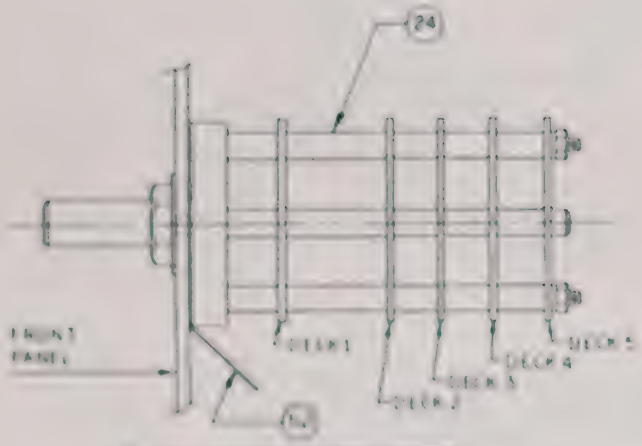
TP	VDC	VAC
1	ac only	0.1
2	0.0	0.002
3	±1.0	1
4	-0.10	1.2
5	+3.50	-
6	+3.40	-
7	-3.90	
8	+4.0	0.035
9	-0.08	0.055
10	-0.14	0.85
13	-0.03	0.64

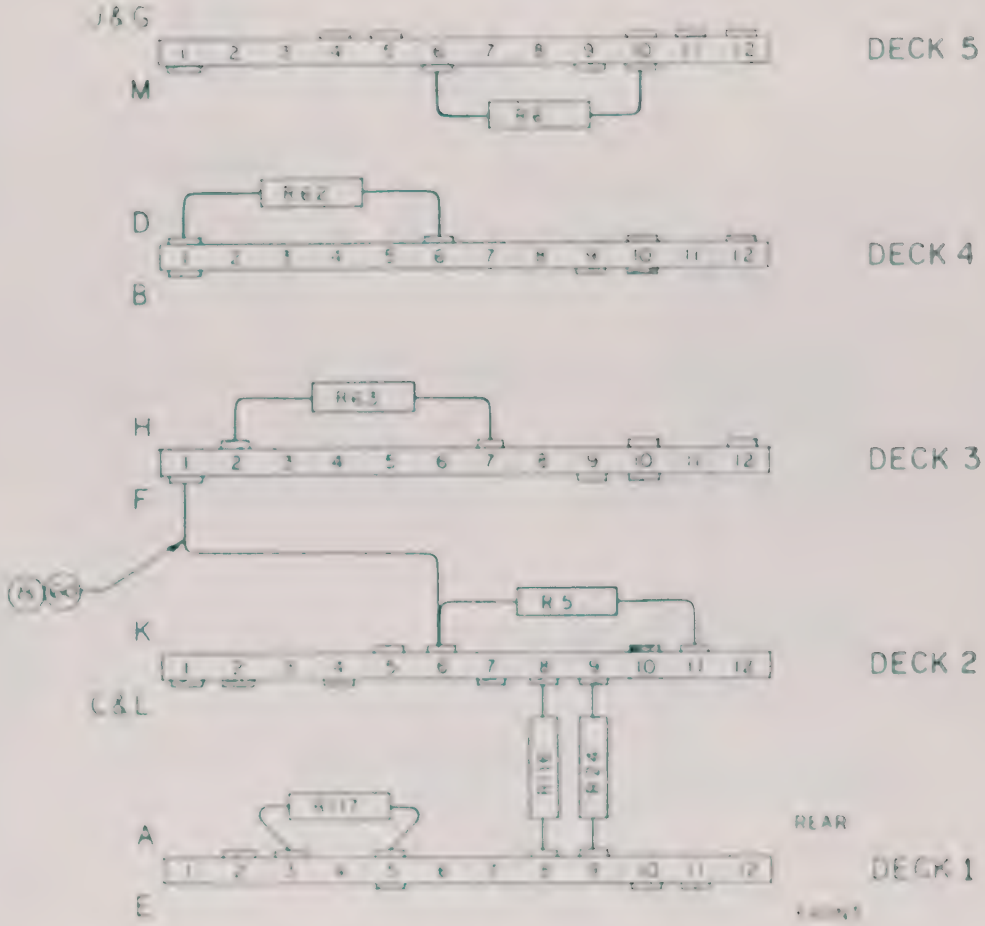
List of Materials - See 7-2, 7-3, 7-4, 7-5

Assembly Drawings - See 6.2.1 and 6.2.2

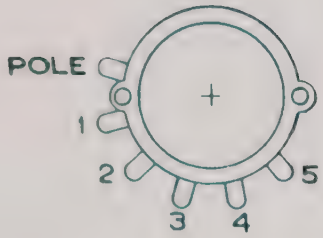
RETURN LOSS
MEASURING SET
KS-20501 L4A

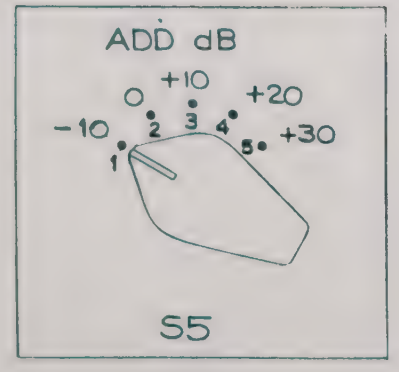
MAIN SCHEMATIC

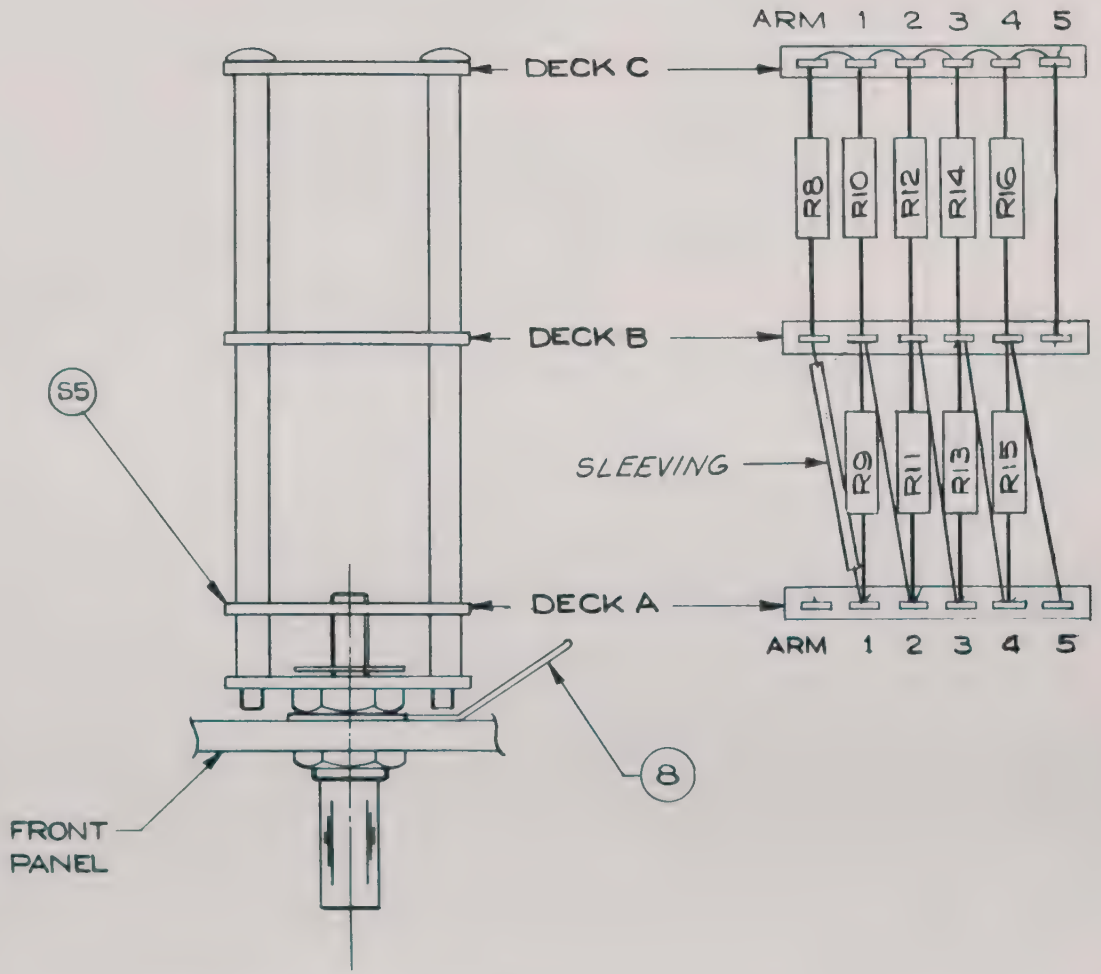




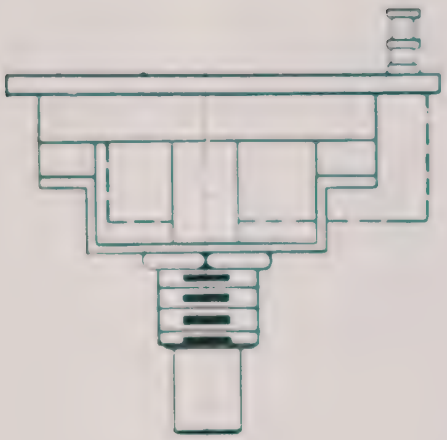
RETURN LOSS MEASURING SET
Switch Detail Test Location
L3 and L4

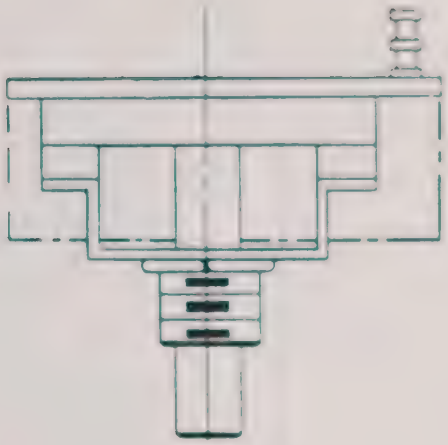


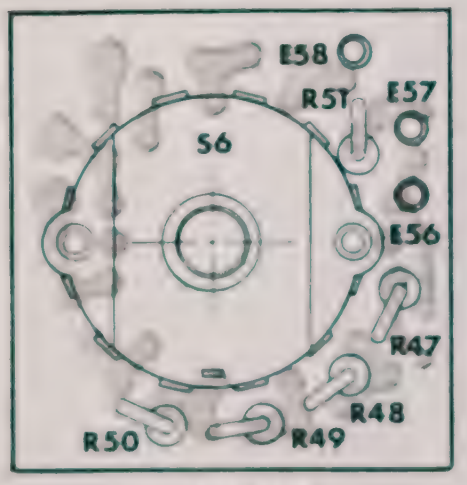


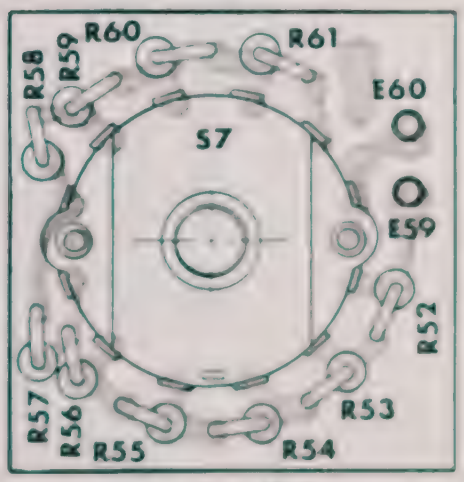


RETURN LOSS MEASURING SET
Switch Detail Add dB
L3 and L4

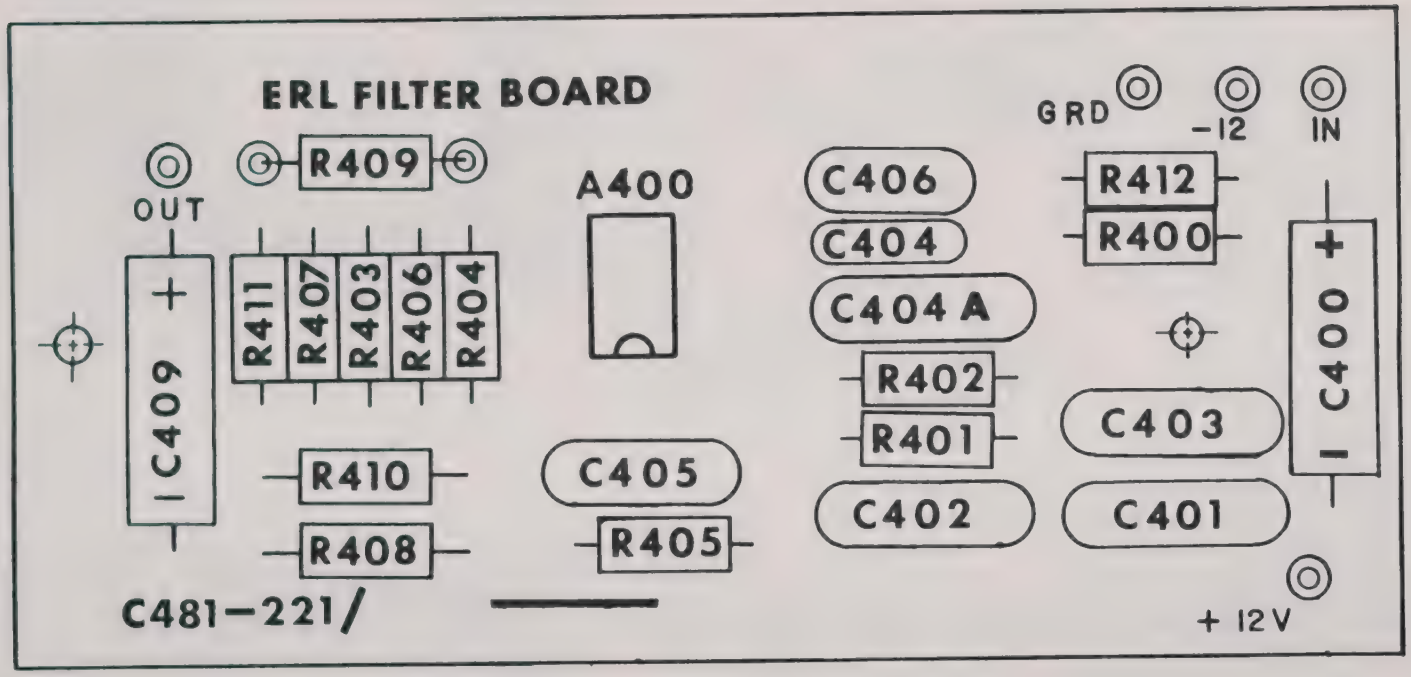


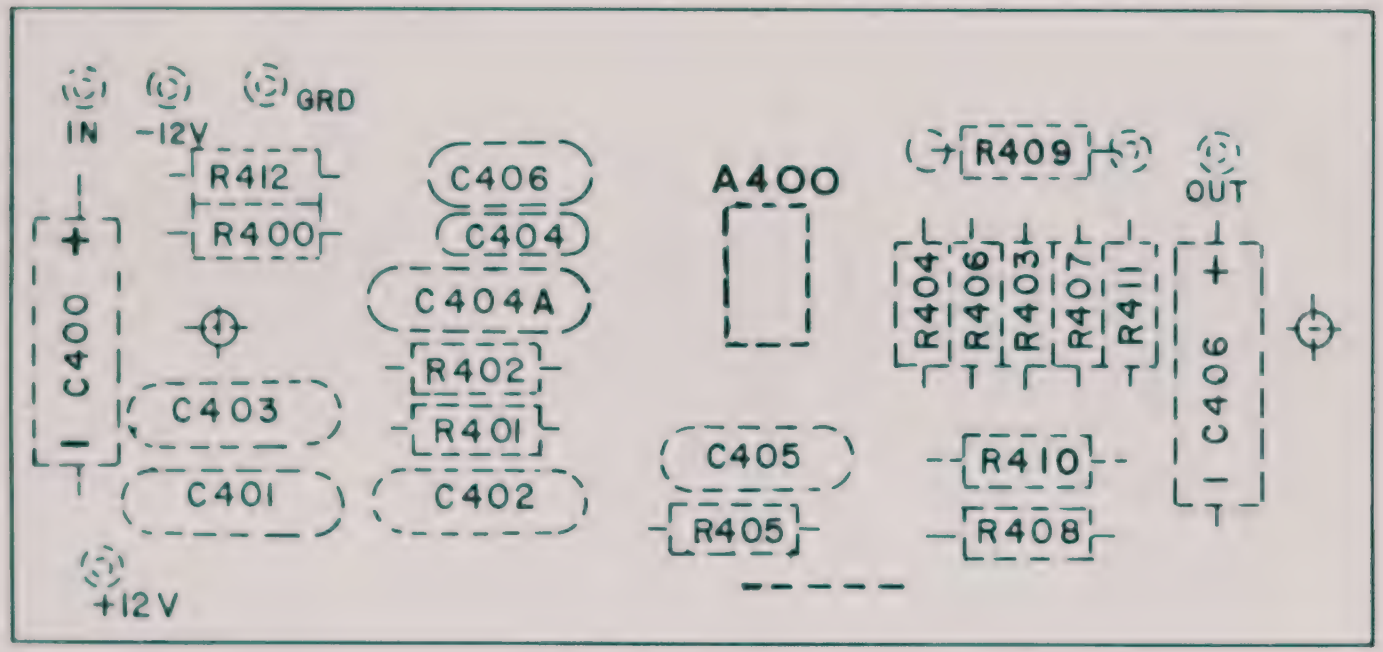



E58
R57
E57
S6
E56
R47
R48
R50
R49


R60
R61
R58
R59
E60
S7
E59
R52
R57
R56
R55
R54
R53

B481-221 sheet 1
6.2.17




IN
-12V
GRD
R412
R400
C400
C403
C401
+12V
C406
C404
C404A
R402
R401
C402
A400
C405
R405
R409
OUT
R404
R406
R403
R407
R411
C406
R410
R408

7.0 PARTS LIST

7.1 General

The parts list itemizes all electrical parts by circuit number. Certain hardware items, such as screws, washers, etc., are not included as these are identifiable and readily available. Generally, the manufacturer's name has been included; however, where the item is a standardized RETMA part, no manufacturer is designated and the product of a registered manufacturer should be acceptable.

Certain items within this parts list may have Bowmar/ALI (ALI) part numbers although they are not manufactured by Bowmar/ALI; these items are purchased to the ALI specification control drawing, as indicated in the parts list.

○ designates those parts found only in the L3 Set.

□ designates those parts found only in the L4 Set.

SYMBOL NUMBER	COMPONENT DESCRIPTION	COMPONENT MANUFACTURER	PART NO.
MAIN BOARD - 6.2.1, 6.2.3 (Filter Schematic - 6.2.12, 6.2.13)			
A1, 3	Integrated Circuit	Harris	HA1-2625-5
A2, 4, 7	Integrated Circuit	RCA	CA3140AE
A5	Integrated Circuit	RCA	CA3030
A6	Integrated Circuit	RCA	CA3000
C1,2,21,22	Capacitor, Electrolytic, 88uf, 150V	Sprague	39D886F150JE4
C3	Capacitor, Disc., .01uF, 20%		CK63AW103M
C6,7,12,13,17,20,25, C26,30,34,46,47,56, C57,58,59,60	Capacitor, .1uF, 20V	Centralab	UK20-104
C8,9,27,42,50,51, C350, 352	Capacitor, Electrolytic, 50uF, 3V	Sprague or Capar	TE-1058E or CAE-E-47M10V
C14, 15, 16	Capacitor, Polyester, 2.16uF, 1%	ALI	C5731
C18, 19	Capacitor, Mica, 220pf, 500V, 5%	CDE	CM05FD221J03
C28,36,39	Capacitor, Electrolytic, 6uF, 25V	Sprague or Capar	TE-1203E or CAE-E-10M25V
C29	Capacitor, Electrolytic, 100uF, 10V	Sprague or Corning	150D Type or CCZ-010-107-20
C35	Capacitor, Electrolytic, 50uF, 25V	Sprague or Capar	TE-1209E or CAE-E-47M25V
C37,38,40,41	Capacitor, Electrolytic, 10uF, 25V	Sprague or Capar	TE-1204E or CAE-E-10M25V
C43, 52	Capacitor, Electrolytic, 300uF, 6V	Sprague or Capar	TE-1106E or CAE-E-330M6.3V
C48	Capacitor, Electrolytic, 25uF, 25V	Sprague or Capar	TE-1207E or CAE-E-22M25V
C49	Capacitor, 50uF, 12V	Sprague or Capar	TE-1133E or CAE-E-47M16V
C53,54,55	Capacitor, 25uF, 25V	Sprague or Capar	TE-1207E or CAE-E-22M25V
C300, 301	Capacitor, Mica, 9100pF, 500V, 2%	CDE	CD30FD912G03
C303,305,308,310,313, C316,319,322,323,326, C329,337,341,346	Capacitor, Ceramic, 220pF, 1000V, 10%	Centralab	DD221
C304	Capacitor, Mica, 4700pF, 500V, 2%	CDE	CD19FD472G03
C306A	Capacitor, Mica, 1800pF, 500V, 2%	CDE	CD19FD182G03

SYMBOL NUMBER	COMPONENT DESCRIPTION	COMPONENT MANUFACTURER	PART NO.
MAIN BOARD - 6.2.1, 6.2.3 [Con't] (Filter Schematic - 6.2.12, 6.2.14)			
C304B	Capacitor, Mica, 6800pF, 500V, 2%	CDE	CD10FD682G03
C304C	Capacitor, Mica, 100pF, 500V, 2%	CDE	CD10FD101G03
C318A, 318B	Capacitor, Mica, 4300pF, 500V, 2%	CDE	CD19FD432G03
C319B	Capacitor, 33pF, 500V, 5%		CM04ED330J03
C307A	Capacitor, 62pF, 500V, 5%		CM04ED620J03
C308	Capacitor, MICA, 9600pF, 500V, 2%	CDE	CD19FD962G03
C307	Capacitor, Mica, 5600pF, 500V, 2%	CDE	CD19FD562G03
C309	Capacitor, Mica, 3900pF, 500V, 2%	CDE	CD19FD392G03
C311,312,324,325	Capacitor, Mica, 5600pF, 500V, 2%	CDE	CD19FD562G03
C314,315,327,328	Capacitor, Mica, 1000pF, 500V, 2%	CDE	CD19FD102G03
C330, 331, 332C	Capacitor, Mica, 220pF, 500V, 2%	CDE	CD10FD221G03
C329A	Capacitor, Mica, 2700pF, 500V, 2%	CDE	CD19FD272G03
C329B	Capacitor, Mica, 200pF, 500V, 2%	CDE	CM04FD201J03
C329A	Capacitor, Mica, 20,000pF, 500V, 2%	CDE	CD30FD203G03
C193A, 319A	Capacitor, Mica, 150pF, 500V, 2%	CDE	CD15FD151G03
C335, 336B	Capacitor, Mica, 2000pF, 500V, 2%	CDE	CD19FD202G03
C336B, 335B	Capacitor, Mica, 18pF, 500V, 5%	CDE	CD10ED180J03
C343	Capacitor, Mica, 1300pF, 500V, 2%	CDE	CD19FD132G03
C344	Capacitor, Mica, 750pF, 500V, 2%	CDE	CD19FD751G03
C155	Capacitor, Ceramic, 51pf		CM04ED510J03
C334	Capacitor, Mica, 100pf		CM04ED101J03
CR1,2,3,4,6,7,8,9, CR12,13,14,15,17	Diode		1N914 or 1N4148
CR1	Diode, Zener, Noise Generator	Sawmar	BYT30
CR15	Diode, Zener, 12V, 2%	Schauer	4Z12
RV1, 2	Surge Protector	Siemens	S1-C143
Q306,303,304,305, Q308,311,312,315, Q316,318,320,321, Q324,325	Transistor		MPS3904 or 2N3904
Q301,302,309,310, Q309,313,314, Q317,319,321,322, Q326,T02	Transistor		MPS3906 or 2N3906

SYMBOL NUMBER	COMPONENT DESCRIPTION	COMPONENT MANUFACTURER	PART NO.
MAIN BOARD - 6.2.1, 6.2.3 (Con't) (Filter Schematic - 6.2.12, 6.2.13)			
R1, 4	Resistor, 1.00K, 1/8W, 1%		RN60C1001F
R2, 3	Resistor, 562 ohm, 1/8W, .25%		RN60C5620C
R17, 18, 330	Resistor, 10.0K, 1/8W, 1%		RN60C1002F
R19, 350, 360, 361	Resistor, 100K, 1/8W, 1%		RN60C1003F
R20,21,29,30,43,44, R67,69,78,80,98,99	Resistor, 100 ohm, 1/4W, 5%		RC07GF101J
R334, 335	Resistor, 20K ohm, 1/8W, 1%		RN60C2002F
R301A	Resistor, 2.7M, 1/4W, 5%		RC07GF275J
R22	Resistor, 4.42K, 1/8W, 1%		RN60C4421F
R23	Resistor, 124 ohm, 1/8W, 1%		RN60C1240F
R26, 92	Resistor, 4.75K, 1/8W, .25%		RN60C4751C
R27	Resistor, 4.99K, 1/8W, .25%		RN60C4991C
R28	Resistor, 49.9K, 1/8W, .25%		RN60C4492C
R31	Resistor, 549 ohm, 1/8W, .25%		RN60C5490C
R32, 34, 36	Resistor, 600 ohm, 1/8W, 0.1%		RN60C6000B
R33, 35, 37	Resistor, 900 ohm, 1/8W, 0.1%		RN60C9000B
R38, 112	Resistor, 4.7K, 1/4W, 5%		RC07GF472J
R39,303,308,312,317, R322,328,332,338,344, R349,353,359,363,369	Resistor, 1.5K, 1/4W, 5%		RC07GF152J
R40,42,64,70,72,82	Resistor, 1K, 1/4W, 5%		RC07GF102J
R41,68,319A	Resistor, 100K, 1/4W, 5%		RC07GF104J
R45,46,87,88,95,104, R376, 378	Resistor, 10K, 1/4W, 5%		RC07GF103J
R65	Resistor, nominal value, 820 ohm, 1/4W, 5%		RC07GF820J
R66,83,84,85,86	Resistor, 2K, 1/4W, 5%		RC07GF202J
R71, 77, 1, 4	Resistor, 5.1K, 1/4W, 5%		RC07GF512J
R73	Resistor, 1.21K, 1/8W, 1%		RN60C1211F
R74, 94	Potentiometer, 500 ohm, 3/4W	Beckman, Bourns, IRC	77PR500, 3006W-1-501, Type 980-20
R75	Resistor, 3.48K, 1/8W, 1%		RN60C3481F
R383	Resistor, 3K, 1/4W, 5%		RC07GF302J

SYMBOL & PAGES	COMPONENT DESCRIPTION	COMPONENT MANUFACTURER	PART NO.
MAIN BOARD - 6.2.1, 6.2.3 (Con't) (Filter Schematic - 6.2.12, 6.2.13)			
R76, 81	Resistor, 510K, 1/4W, 5%		RC07GF514J
R89, 90	Resistor, 160K, 1/4W, 5%		RC07GF164J
R93	Resistor, 150K, 1/4W, 5%		RC07GF154J
R94	Resistor, 562 ohm, 1/8W, 1%		RN60C5620F
R100, 101	Resistor, 8.2K, 1/4W, 5%		RC07GF822J
R102	Potentiometer, 1K, 3/4W	Beckman, Bourns, IRC	7[illegible], 3006W-1-102, Type 980-90
R105, 106	Resistor, 270 ohm, 1/4W, 5%		RC07GF271J
R107, 108	Resistor, 620 ohm, 1/4W, 5%		RC07GF621J
R109, 113	Resistor, 5.6K, 1/4W, 5%		RC07GF562J
R110	Resistor, 2.4K, 1/4W, 5%		RC07GF242J
R118, 119, 120, 121, R122, 123	Resistor, 300 ohm, 1/4W, 5%		RC07GF301J
R114	Resistor, 510 ohm, 1/4W, 5%		RC07GF511J
R341A	Resistor, 43K, 1/4W, 5%		RC07GF433J
R342A	Resistor, 620K, 1/4W, 5%		RC07GF624J
R79	Resistor, 20K, 1/4W, 5%		RC07GF203J
R115, [illegible]	Resistor, 68 ohm, 1/4W, 5%		RC07GF680J
R124	Resistor, 1.2K, 1/4W, 5%		RC07GF122J
R301	Resistor, 20.5K, 1/8W, 1%		RN60C2052F
R320,342,351	Resistor, 187K, 1/8W, 1%		RN60C1873F
R302,306,311,315,321, R326,331,336,343,347, R352,357,362,367	Resistor, 220 ohm, 1/4W, 5%		RC07GF221J
R304,307,313,316,323, R327,333,337,345,348, 354,358,364,368	Resistor, 7.5K, 1/4W, 5%		RC07GF752J
R305	Resistor, 80.6K, 1/8W, 1%		RN60C8062F
R309, 310	Resistor, 150K, 1/8W, 1%		RN60C1503F
R324	Resistor, 133K, 1/8W, 1%		RN60C1333F
R329	Resistor, 19.1K, 1/8W, 1%		RN60C1912F
R339	Resistor, 255K, 1/8W, 1%		RN60C2553F
R340A	Resistor, 620K, 1/4W, 5%		RC07GF624J

SYMBOL NUMBER	COMPONENT DESCRIPTION	COMPONENT MANUFACTURER	PART NO.
MAIN BOARD - 6.2.1, 6.2.3 (Con't) (Filter Schematic - 6.2.12, 6.2.13)			
R325, 301	Resistor, 221K, 1/8W, 1%		RN60C2213F
R341	Resistor, 1.15K, 1/8W, 1%		RN60C1151F
R346	Resistor, 13.7K, 1/8W, 1%		RN60C1372F
R355, 356	Resistor, 24.3K, 1/8W, 1%		RN60C2432F
R365, 366	Resistor, 110K, 1/8W, 1%		RN60C1103F
R375	Resistor, 143K, 1/8W, 1%		RN60C1433F
R300A, 319A, 341A, R346A, 375A	Resistor, select		
R102	Resistor, 1.3K, 1/4W, 5%		RC07GF132J
R381, 379	Potentiometer, 100K	Bourns, TRW, Dale	3006P, 961-20, 785, 10%
T1, 2	Transformer	AIE	95-207
AC POWER SUPPLY - 6.2.6 (Schematic - 6.2.8)			
C206,207,209,210	Capacitor, 100uF, 50V	Sprague or Capar	TE-1309E or CAE-E-47M25V
C208	Capacitor, 800uF, 3V	Sprague	500D807G003DH7
CR201	Bridge Rectifier	Varo	VE18
CR203, 204	Diode		1N914
CR205	Diode, Zener, 10V, 2%	Schauer	SZ10
Q204	Transistor	RCA	40409
Q205	Transistor		2N5135
Q206	Transistor		2N5142
Q207	Transistor	RCA	40410
R210,211,212,213	Resistor, 1.5K, 1/2W, 5%		RC20GF152J
R214, 215	Resistor, 220 ohm, 1/2W, 5%		RC20GF221J
R216	Resistor, 6.2K, 1/2W, 5%		RC20GF622J
R217	Resistor, 5.6K, 1/2W, 5%		RC20GF562J
T201	Transformer, power	Microtran	M8290

SYMBOL & VALUE	COMPONENT DESCRIPTION	COMPONENT MANUFACTURER	PART NO.
DC POWER SUPPLY - 6.2.9 (Schematic - 6.2.11)			
[illegible]	Capacitor, 47uF, 50V	Siemens	B41283-47/40/8100C
[illegible]	Capacitor, .22uF, 250V	Amperex	C280AEA220KSR
[illegible]	Capacitor, 0.01uF, 63V	Siemens	B41010-220/63-82000
[illegible]	Capacitor, 100uF, 25V	Sprague or Capar	TE-1211E or CAE-E-100M25V
C208	Capacitor, 800uF, 3V	Sprague	[illegible]
C211	Capacitor, .01uF, 1K V, 20%	Centralab	[illegible]
C212,213	Capacitor, 10uF, 100V	Sprague or Capar	[illegible] CAE-E-10M100V
CR201,202,208	Diode		1N4001
CR203, 204	Diode		1N914
CR205	Diode, Zener, 10V, 2%	Schauer	[illegible]
CR206, 207	Diode, Zener		1N4743
L200	Choke, R.F., 22uH, ± 10%	Cambion	[illegible]
Q200	Transistor, unijunction	GE	[illegible]
Q201	Transistor		[illegible]
Q202, 204	Transistor	RCA	[illegible]
Q203, 207	Transistor	RCA	40410
[illegible]	Transistor		2N5135
[illegible]	Transistor		[illegible]
[illegible]	Resistor, 1.6K, 1/2W, 5%		[illegible]
[illegible]	Resistor, 100 ohm, 1/2W, 5%		[illegible]
[illegible]	Resistor, 9.1K, 1/2W, 5%		[illegible]
[illegible]	Resistor, 1.8K, 1/2W, 5%		[illegible]
[illegible]	Resistor, 68K, 1/2W, 5%		[illegible]
[illegible]	Resistor, 3.3K, 1/2W, 5%		[illegible]
[illegible]	Resistor, 6.8K, 1/2W, 5%		[illegible]
[illegible]	Resistor, 5.1K, 1/2W, 5%		[illegible]
[illegible]	Resistor, 180 ohm, 1/2W, 5%		[illegible]
R214,211,212,213	Resistor, 750 ohm, 1/2W, 5%		[illegible]
R214, 215	Resistor, 220 ohm, 1/2W, 5%		[illegible]
[illegible]	Resistor, 6.2K, 1/2W, 5%		[illegible]
[illegible]	Resistor, 5.6K, 1/2W, 5%		[illegible]
[illegible]	Resistor, 1K, 1/2W, 5%		RC20GF102J

SYMBOL NUMBER	COMPONENT DESCRIPTION	COMPONENT MANUFACTURER	PART NO.
FRONT PANEL AND CHASSIS MOUNTED PARTS (Main Schematic - 6.2.12, 6.2.13)			
C61, 62	Capacitor, Electrolytic, 100uF, 25V	Sprague or Capar	TE-1121E or CAE-E-100M25V
F1, 2, 4, 5, 6, 7, 8	Binding post, black	H.H. Smith	897
F3	Binding post, metal	H.H. Smith	1835
F1	Fuse, 1/10 A, slow blow, 3AG	Littlefuse	313.100
J1, 2, 3, 4	Phone Jack	Switchcraft	MT-332B
M1	Meter, SCD	ALI	C5864
R5, 6, 62, 63	Resistor, 150 ohm, 1/8W, 1%		RN60C1500F
R8	Resistor, 965 ohm, 1/8W, .25%		RN60C9650C
R9,11,13,15	Resistor, 2.1K, 1/8W, .25%		RN60C2101C
R10,12,14	Resistor, 1.43K, 1/8W, .25%		RN60C1431C
R16	Resistor, 1.07K, 1/8W, .25%		RN60C1071C
R24	Resistor, 96.5K, 1/8W, .25%		RN60C9652C
R47	Resistor, 1.30K, 1/8W, .25%		RN60C1301C
R48	Resistor, 1.27K, 1/8W, .25%		RN60C1271C
R49	Resistor, 1.37K, 1/8W, .25%		RN60C1371C
R50	Resistor, 1.40K, 1/8W, .25%		RN60C1401C
R51	Resistor, 2K, 1/8W, .25%		RN60C2001C
R52	Resistor, 301 ohm, 1/8W, .25%		RN60C3010C
R53	Resistor, 336 ohm, 1/8W, .25%		RN60C3360C
R54	Resistor, 379 ohm, 1/8W, .25%		RN60C3790C
R55	Resistor, 427 ohm, 1/8W, .25%		RN60C4270C
R56	Resistor, 475 ohm, 1/8W, .25%		RN60C4750C
R57	Resistor, 536 ohm, 1/8W, .25%		RN60C5360C
R58	Resistor, 604 ohm, 1/8W, .25%		RN60C6040C
R59	Resistor, 673 ohm, 1/8W, .25%		RN60C6730C
R60	Resistor, 759 ohm, 1/8W, .25%		RN60C7590C
R61	Resistor, 845 ohm, 1/8W, .25%		RN60C8450C
R116, 117, 124	Resistor, 2.37K, 1/8W, .25%		RN60C2371C
S1	Switch, SPDT, toggle	C & K	7101
S2	Switch, 12P, 5P, Rotary	CTS	ALI B5871
S3	Switch, 3P, 3P, Rotary	CTS	ALI B5873
S3	Switch, 2P, 2P, Rotary	CTS	ALI B5872
S4	Switch, 1P, 4P, Rotary	CTS	ALI B5870
S5	Switch, 1P, 5P, Rotary	CTS	ALI B5867
S6	Switch, 1P, 5P, Rotary	CTS	ALI B5868
S7	Switch, 1P, 11P, Rotary	CTS	ALI B5869
XF1	Fuseholder	Littlefuse	342004

SYMBOL & POSITION	COMPONENT DESCRIPTION	COMPONENT MANUFACTURER	PART NO.
[illegible] - 6.2.17 (Schematic - 6.2.18)			
C406, 409	Capacitor, Electrolytic, 50uF, 3V	Sprague or Capar	TE-1058E or [illegible]
C401, 407	Capacitor, DSM ± 2%, 1000pF, 500V	CDE	CD15FD102G03
C403, 404A	Capacitor, DSM 2000pF, 500V, ± 2%	CDE	CD19FD202G03
C404	Capacitor, DSM 330pF, 500V, ± 2%	CDE	CD15FD331G03
C405, 408	Capacitor, Ceramic, 0.1uF, 20V, +80-20%	Centralab	UK20-104
R401, 406	Resistor, 34.0K, 1/8W, ± 1%		RN60C3402F
R400	Resistor, 10.0K, 1/8W, ± 1%		RN60D1002F
R407	Resistor, 16.9K, 1/8W, ± 1%		RN60C1692F
R404	Resistor, 107K, 1/8W, ± 1%		RN60C1073F
R403, 405, 412	Resistor, 100 ohm, 1/4W, ± 5%		RC07GF101J
R408	Resistor, 1.5K, 1/4W, ± 5%		RC07GF152J
R402	Resistor, 280K, 1/8W, ± 1%		RN60C2803F
R410	Resistor, 560 ohm, 1/4W, ± 5%		RC07GF561J
R409, 411	Resistor, 10K, 1/4W, ± 5%		RC07GF103J
A400	Integrated Circuit	RCA	CA3140AE

LIST OF MANUFACTURERS

Abbreviation	Complete Name and Address
AIE	AIE Division of Vernitron 701 Murfreesboro Road Nashville, TN 37210
ALI	Bowmar/ALI, Inc. 531 Main Street Acton, MA 01720
Amperex	Amperex Electronic Corporation Providence Pike Slatersville, RI 02876
Beckman	Beckman Instruments 2500 Harbor Boulevard Fullerton, CA 92634
Bourns	Bourns, Inc. 1200 Columbia Avenue Riverside, CA 92507
C & K	C & K Components, Inc. 15 Riverdale Avenue Newton, MA 02158
Cambion	Cambridge Thermionic Corporation 445 Concord Avenue Cambridge, MA 02138
Capar	Capar 110 Marcus Drive Melville, NY 11747
CDE	Cornell-Dublier Electronics 150 Avenue "L" Newark, NJ 07105
Centralab	Centralab, Inc. 5757 North Green Bay Avenue Milwaukee, WI 53201
Corning	Corning Electronics Corning Glass Works Corning, NY 14830
CTS	CTS Keene, Inc. 3230 Riverside Avenue Paso Robles, CA 93446

Dale	Dale Electronics, Inc. Box 609 Columbia, NB 68601
G.E.	General Electric Company 1 River Road Schenectady, NY 12345
General Radio	General Radio Company 300 Baker Avenue West Concord, MA 01781
Harris	Harris Semiconductor Box 883 Melbourne, FL 32901
IRC	International Rectifier Corp. 233 Kansas Street El Segundo, CA 90245
Littlefuse	Littlefuse, Inc. 800 East Northwest Highway Des Plaines, IL 60016
Microtran	Microtran Company, Inc. 145 East Mineola Avenue Valley Stream, NY 11582
RCA	RCA Solid State Division Route 202 Somerville, NJ 08876
Schauer	Schauer Manufacturing Company 4500 Alpine Avenue Cincinnati, OH 45242
Siemens	Siemens Corporation 186 Wood Avenue South Iselin, NJ 08830
Sprague	Sprague Electric Company 481 Marshall Street North Adams, MA 01247
Switchcraft	Switchcraft, Inc. 5555 North Elston Chicago, IL 60630

TRW	TRW Capacitors 301 West "O" Street Ogallala, NB 69153
Varo	Varo Semiconductor, Inc. 2800 West Kingsley Drive Garland, TX 75040

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